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p. 77, 11 l. from top, for California read Greenland.
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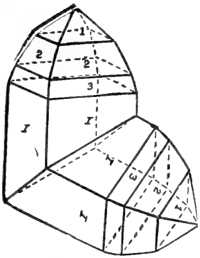
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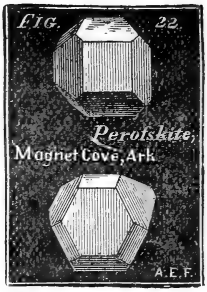
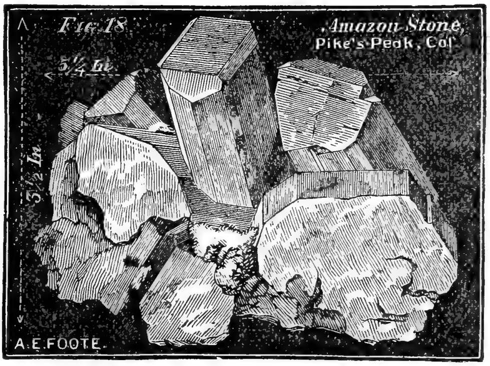


Fig. 22.
Perofskite,
Magnet Cove, Ark.
A.E.F.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Amazon Stone,
Pike's Peak, Col.
5¼ In.
3½ In.
A. E. FOOTE.

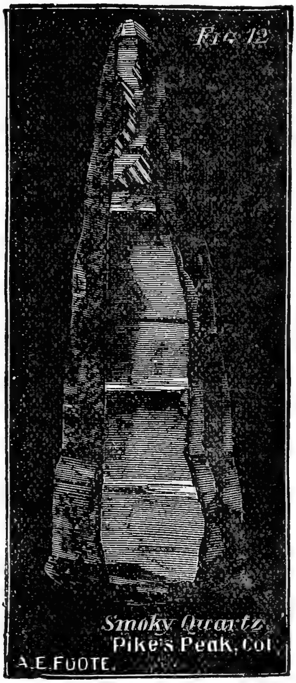


Fig. 12.
Smoky Quartz,
Pike's Peak, Col.
A. E. FOOTE.


Fig.
Brookite
Truncated 1.
A. E. FOOTE.

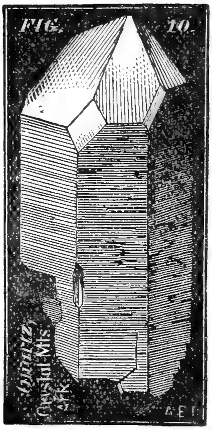
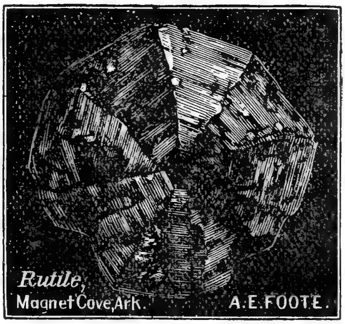


Fig. 10.
Quartz
Crystal Mts.
Ark.
A. E. F.


Rutile,
Magnet Cove, Ark.
A. E. FOOTE.

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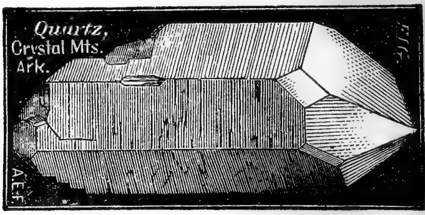

Quartz,
Crystal Mts.
Ark.
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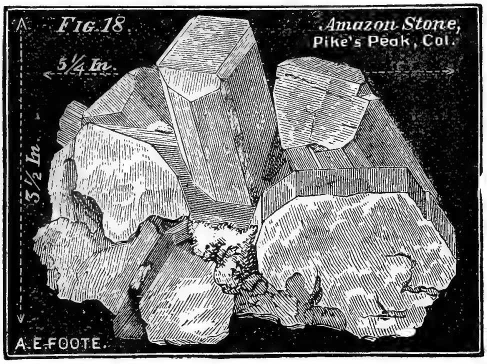

FIG. 18.
Amazon Stone,
Pike's Peak, Col.
5¼ In.
3½ In.
A.E.FOOTE.

FIG. 4.
Brookite,
Truncated 1.
A.E.FOOTE.

Hydro-
Ark.
A.E.F.

Chas. D. Walcott.

THE
AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. I.—*Memorial of* EDWARD TUCKERMAN ; by ASA GRAY.*

ON the 15th of March last, the Academy lost one of the older and more distinguished members of the botanical section, the Lichenologist, EDWARD TUCKERMAN.

He was born in Boston, December 7, 1817, was the eldest son of a Boston merchant of the same name and of Sophia (May) Tuckerman. He was prepared for college at the Boston Latin School, whence, in obedience to his father's choice rather than of his own, he went to Union College at Schenectady. Entering as a Sophomore, he took his B.A. degree in 1837. He then entered the Harvard Law School, took his degree in 1839, and remained in residence in Cambridge for a year or two longer. In the year 1841 he went to Germany and Scandinavia, going as far north as Upsala, devoting himself, as in a subsequent visit, to philosophical, historical, and botanical studies. On his return, in September, 1842, he made, with the writer of this notice, a botanical excursion to the White Mountains of New Hampshire, with which he was already familiar. At the close of that or early in the following year he took up his residence at Union College, proceeded to the M.A. degree, and there prepared and privately published one of the smaller, but noteworthy, of his botanical papers.

In the year 1844 or 1845 he returned to Cambridge, and in the autumn of 1846, in his twenty-ninth year, he became again

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* From the Proceedings of the American Academy of Arts and Sciences, vol. xxi, 1886.

an undergraduate. Applying for admission to the incoming senior class, he remarked to President Quincy that his father had broken the family tradition by sending him to another college, and that he proposed to correct the mistake. To the suggestion, that, being already an alumnus of the Law School as well as of Union, the University would willingly concede to him the earlier degrees he sought, he replied that he proposed to receive them in the ordinary way. He accordingly passed the regular examinations, took the whole routine of the studies of his class, and so was graduated with distinction in the class of 1847,—a unique but characteristic illustration of a loyal spirit, becoming "small by degrees and beautifully less."

His passion for university study was not yet quite satiated. For, two or three years later, he entered the Harvard Divinity School, passed through its course of study and prescribed exercises,—among them the delivery of a sermon in one of the Cambridge churches,—and so, in the year 1852, he became for the third time an alumnus of Harvard.

In May, 1854, he married in Boston Sarah Eliza Sigourney Cushing, who survives him, without offspring. Removing that year to Amherst, he built, with excellent taste, upon a beautiful site, the house which has ever since been their abode. Although mainly devoted to botanical investigations, his first official connection with Amherst College was that of Lecturer in History, then that of Professor of Oriental History, down to the year 1858, when he was collated to the chair of Botany, which he held to the end of his life, although of late years relieved from the duty of class instruction. The College did itself the honor to confer upon its professor the degree of LL.D.

We cannot say when or how Professor Tuckerman became a botanist. But at an early period he was intimate with Dr. Harris, then University Librarian, and with the ardent William Oakes of Ipswich, upon whom, through Dr. Osgood of Danvers, descended the mantle of Manasseh Cutler, of Essex County, the earliest New England botanist.

He must have been attracted to the Lichens almost from the beginning. For his first publications were upon Lichens of New England, largely those of his own collecting in the White and Green Mountains, in two papers, one communicated to the Boston Natural History Society in 1838 or 1839, the other in 1840. These were soon followed by papers on phænogamous botany, viz: one "On *Oakesia* a new Genus of the Order *Empetreæ*," a contribution made while he was abroad, in the summer of 1842, to Hooker's London Journal of Botany. Unfortunately, the interesting plant which he thus dedicated to his botanical associate, William Oakes, who well deserved such commemoration, proved to be a second species of *Corema*. In

1843, at Schenectady, he privately printed and issued his "Enumeratio Methodica Caricum quarundam," (pp. 21, 8vo), in which he displayed not only his critical knowledge of the large and difficult genus *Carex*, but also his genius as a systematizer; for this essay was the first considerable, and a really successful, attempt to combine the species of this genus into natural groups. It is wholly in Latin, which he much affected for scientific disquisition as well as for technical characters, and used with facility and elegance. In the same year also appeared, in the American Journal of Science, the first of his "Observations on some interesting Plants of New England." This was followed in 1848 by a second, and in 1849 by a third paper in the same Journal; these containing, *inter alia*, his elaboration of our species of *Potamogeton*, then for the first time critically studied. These papers—with one or two in Hovey's Magazine and elsewhere, at about the same date—may be said to have ended his work in phænogamous botany, although his interest in the subject never died out. For when he accepted the chair of Botany at Amherst he began the preparation of "A Catalogue of Plants growing without cultivation within thirty miles of Amherst College," which he published in the year 1875, the late Mr. Charles Frost of Brattleborough contributing the lower Cryptogamia other than the Lichens. In matter and form, as well as in typography (in which Professor Tuckerman had exquisite taste), this catalogue is one of the very best.

But it was to Lichenology that his strength, as indeed almost his whole life, was most assiduously devoted. When, in his youth, the active members of the newly organized Natural History Society of Boston divided among themselves the work of making better known the animals, plants, and minerals of Massachusetts, the study of the Lichens either was assigned to him or he volunteered to undertake it. From this came those earliest papers which have already been mentioned. Also his "Synopsis of the Lichens of New England, the other Northern States, and British America," communicated to this Academy in the autumn of 1847, which is the most considerable botanical contribution to the first volume of the Proceedings. The fourth, fifth, sixth, and seventh volumes contain other of his lichenological papers, of wholly original matter and critical character,—largely upon collections which had begun to come to him from the Rocky Mountain region, from Texas, the Pacific Coast, the Sandwich Islands, and especially from the rich materials gathered in Cuba and elsewhere by the late Charles Wright. In these years, too, he much helped the study of his favorite plants by the preparation and issue of his "Lichenes Americæ Septentrionalis Exsiccati," in six fasciculi, or three volumes, highly valued by those who fortunately possess them. Equally fortunate are the herbaria which possess the "Caroli Wrightii Lichenes Cubæ curante E. Tuckerman," which authenticate his thorough work upon that portion of Mr. Wright's Cuban collections that he undertook to elaborate.

Passing without notice various subsidiary contributions both to journals and to the Reports of Exploring Expeditions (which, however, are all enumerated in the appended list), we come to a pamphlet which he independently published at Amherst, in 1866, entitled "Lichens of California, Oregon, and the Rocky Mountains, so far as yet known," which, small though it be (pp. 35, 8vo), is particularly noteworthy. For in this he lays down the principles and matured opinions which he had adopted, and which he firmly adhered to, for the taxonomy and classification of Lichens. These are fully exemplified in the two systematic works to which Professor Tuckerman's later years and maturest powers were persistently devoted,—works which, partly from their publication somewhat out of the ordinary channels, are by no means so well known as they should be, but which surely secure to their author the position of a master in his department,—in which, indeed, we suppose he has left behind him no superior. These works are, first, the "Genera Lichenum, an Arrangement of the North American Lichens" (pp. 283, 8vo), published at Amherst in the year 1872; second, the "Synopsis of the North American Lichens," Part I, comprising the *Parmeliacei*, *Cladoniei* and *Cœnogoniei*, published in Boston (by Cassino & Co.) in 1882. It is hoped, but it is not yet certain, that some portions of the remainder, relating to the less conspicuous but more difficult tribes, may have been substantially made ready for the printer. The loss, we fear, is irreparable; for the work cannot be completed by other hands upon quite the same lines, nor in our day with the same knowledge and insight; and Professor Tuckerman's mode of exposition is inimitable.

That which Professor Tuckerman did accomplish, however, suffices to show the wide reach and remarkable precision of his knowledge, his patience and thoroughness in investigation, his sagacity in detecting affinities, and his philosophical and rather peculiar turn of mind. He wrote in a style which—though perhaps founded on that of his botanical model, Fries, for succinctness, and that of his favorite German philosophical masters for involution—was yet all his own, and which was the more pronounced in advancing years, when, owing to increasing deafness and delicate health, he led a more secluded life. In disquisition, the long and comprehensive sentences which he so carefully constructs are unmistakably clear to those who will patiently plod their way through them, and his choice even of unusual words is generally felicitous; but sometimes the statements are so hedged about and interpenetrated by qualifications or reservations, and so pregnant with subsidiary although relevant considerations, that they are far from easy reading. Like nests of pill-boxes, they are packed into least bulk; but for practical use they need to be taken apart.

That Professor Tuckerman could write idiomatic and clear-flowing English upon occasion, the delightful introduction to his edition of Josselyn's "New England's Rarities" demonstrates; and in the framing of botanical descriptive phrases, Latin or English, in which clearness and brevity with just order and proportion are desiderata, he had hardly a superior.

As has been said, his botanical model was Elias Fries. He had visited him at Upsala, and he kept up a correspondence with him to the end of the venerable botanist's life. He caught from Fries, or he developed independently, and cultivated to perfection, that sense of the value of the indefinable something which botanists inadequately express by the term "habit," which often enables the systematist to *divine* much further than he can perceive in the tracing of relationships. Upon this, in direct reference to Fries, and with a use of the term that seems to correlate it with "insight," Tuckerman remarks: "So great is the value of Habit in minds fully qualified to apprehend and appreciate its subtleties, that such minds may not only anticipate what the microscope is to reveal, but help us to understand its revelations." It should be remembered, however, that when Fries did the best of his work there were no microscopes of much account; and it is probable that Tuckerman would have done more, and perhaps have reached some different conclusions, if he had earlier and more largely used the best instrumental appliances of the time. One advantage, however, of his way of study, and his philosophical conception of an ideal connection of forms which are capable of a wide play of variation, was that he took broad views of genera and species. So he was quite unlike that numerous race of specialists who, in place of characterizing species, describe specimens, and to whom "genus" means the lowest recognizable group of species.

As to the vexed question in Lichenology, which came to him rather late and seemed to threaten the stability of his work, it was most natural that, at his time of life, he did not take kindly to the algo-fungal notion of Lichens, and that he was convinced of its falsity by questionable evidence.

Professor Tuckerman was much more than an excellent specialist. Happily, he did not become such until he had laid a good foundation, for the time, in general systematic botany; and his early studies show that he was a man of scholarly culture over an unusually wide range. He was at home in the leading modern languages; he wrote Latin with reasonable facility, and botanical Latin remarkably well; he had given serious attention to law, divinity, philosophy, and history; and he was fond of antiquarian and genealogical researches. He privately published (without date) a handsome edition of Josselyn's "New England's Rarities Discovered," with copious critical annotations, of 134 pages, including an introduction of 27 pages, which contains a biography of Josselyn and a sketch of the earlier sources of our knowledge of New England plants and of some of the people who made them known.* Among them is a biographical notice of Manasseh Cutler, one of the very first elected Fellows of this Academy, the earliest botanical contributor to its Memoirs,—pastor, naturalist, and statesman, the builder of New England in Ohio, probably the originator of the Dane Resolutions in Congress,—a man whose name deserves larger remembrance than it has yet received.

Professor Tuckerman was elected into this Academy in May, 1845. He was one of the corporate members of the National Academy of Sciences at Washington, and an honorary member of several of the learned societies and academies of Europe. He was still young when Nuttall dedicated to him the genus *Tuckermania*, founded upon one of the handsomer of Californian Compositæ, which holds as a subgenus. For one who did not attain the age of sixty-seven, his publications span a remarkably wide interval. It is said that he contributed several short articles on antiquarian topics to the Mercantile Journal in the year 1832. Also that, in 1832 and 1833, he assisted the late Mr. Samuel G. Drake in the preparation of his "Book of the Indians" and "Indian Wars." Then, between 1834 and 1841, he contributed to the New York Churchman no less than fifty-four articles, under the title of "Notitia Literaria" and "Adversaria," upon points in history, biography and theology. His latest botanical article was contributed to the Bulletin of the Torrey Botanical Club in 1884. A little later, possibly, are some of his contributions to the Church Eclectic, mostly pseudonymous,—critical notices of recent theological works. He was a keen critic, and very independent in his judgments. He had sounded in his time the depth of various opinions. But as he was born into, so he died, as he had lived, devoutly, in the communion of the Protestant Episcopal Church. With some interruptions, and of late under increasing infirmities, he yet continued his lichenological studies until within a few weeks before the end. Living for a long while in comparative seclusion, few of our younger botanists can have

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* It appears that this was a contribution to the fourth volume of the Archæologia Americana, published in 1860.

known him personally, or much by correspondence; and most of his old associates and near friends, who knew him best and prized him highly for his sterling character, have gone before him.

ART. II.—*Notes on American Earthquakes, No.* 15; by Professor C. G. ROCKWOOD, JR., Princeton, N. J.

IN this, the fifteenth paper of this series, I have given, as in former years, a summary of such information as I have been able to gather in regard to the earthquakes of 1885 in North and South America. For the facts embodied herein I am largely indebted to the Monthly Weather Review of the U. S. Signal Service, and to a pretty careful watch of the current newspapers; but I must express here my thanks to all those persons, a somewhat numerous company, who have in one way or another personally lent their aid to my work. Among them I may be permitted to mention J. M. Batchelder, Esq., of Cambridge, Mass., Professor Charles Carpmael of Toronto, Superintendent of the Meteorological Service of Canada, C. H. McLeod of McGill College Observatory, and Dr. George Pyburn of Sacramento, California, who has given very efficient aid in collecting data in regard to Californian earthquakes.

A few items are printed in small type, being regarded as somewhat doubtful, and when the account of any earthquake rests on the authority of a single unconfirmed report, the source of the information is always given. The division of the day into twenty-four hours is again employed.

I have also again attempted to assign to each earthquake a grade of intensity. The estimate of intensity is based whenever possible upon the character of the physical phenomena reported. When no such information is available, the judgment is based upon the phraseology of the original report, taking into account the probable intensity of an earthquake in the locality in question. For example, if a despatch says briefly, "A heavy earthquake was felt" at a single place; then if this item referred to the eastern United States it might mean a *light* or even a *very light* shock, while if it referred to Peru or Central America it would probably be a *strong* or a *severe* shock. I am quite aware that such estimates have in many cases a large element of uncertainty, but at least they are the best that can be made now, and better than any one else could make at a later date and without access to the original reports. In indicating the intensity I have used again the adjectives, 1, *Very light;* 2, *Light;* 3, *Moderate;* 4, *Strong;* 5, *Severe;* 6, *Destructive*, in the same sense as in my last notes (this Journal, xxix, 426); but I have added a Roman numeral to indicate the intensity according to the Rossi-Forel scale* adopted by the Italian and Swiss seismologists. The two scales may be compared thus:

Very light = II or III.
Light = IV.
Moderate = V or VI.
Strong = VI or VII.
Severe = VIII.
Destructive = IX or X.

1885.

Jan. 2.—21^h 12^m, a *light* earthquake (IV) occurred in Frederick County, Maryland, and Loudon County, Virginia, and adjacent districts. It was most severe in the southern part of Frederick County and affected an oval area of about 3,500 square miles, whose boundary just included Boonesborough and Newmarket, Md., Washington, D. C., and Warrenton, Va. The noise accompanying the shock was compared to that made by a loaded wagon passing rapidly over frozen ground or over a bridge, to distant thunder, and to the roaring of a chimney on fire. In some cases persons went out of their houses to see if their chimneys were not burning. The estimates of the duration of the shock were as usual very discordant, varying from two seconds to two minutes. As the tendency is to exaggerate this element, probably ten or fifteen seconds would be a liberal estimate of the duration. A fuller notice of this earthquake, with a map, was published in Science, v, 129.

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* As this scale is not very readily accessible in America (it was printed in Science, v, 197), I reproduce a translation of it here for reference in connection with these papers.

I. Microseismic shock.—Recorded by a single seismograph or by seismographs of the same model but not putting in motion seismographs of different patterns; reported by experienced observers only.

II. Shock recorded by several seismographs of different patterns; reported by a small number of persons at rest.

III. Shock reported by a number of persons at rest; duration or direction noted.

IV. Shock reported by persons in motion; shaking of movable objects, doors and windows; cracking of ceilings.

V. Shock felt generally by every one; furniture shaken; some bells rung.

VI. General awakening of sleepers; general ringing of bells; swinging of chandeliers; stopping of clocks; visible swaying of trees; some persons run out of buildings.

VII. Overturning of loose objects; fall of plaster; striking of church bells; general fright without damage to buildings.

VIII. Fall of chimneys; cracks in the walls of buildings.

IX. Partial or total destruction of some buildings.

X. Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

Jan. 3.—About 2^h a *very light* shock (III), lasting about five seconds, occurred at Laconia, N. H.

Jan. 4.—6^h 6^m, a *light* earthquake (IV) occurred at Peekskill, Sing Sing, Tarrytown and other places along the lower Hudson. It was accompanied by a rumbling sound and was strong enough to shake windows, etc., but owing to the early hour it was not generally noticed, as it was not strong enough generally to awaken sleepers.

Jan. 15.—4^h 10^m, a *very light* shock (III) at Shæfferstown, Pa. —*Philadelphia Record.*

Jan. 18.—About 5^h 30^m or 5^h 45^m, a *very light* shock (II) at Garrettsville, Portage County, Ohio.—*U. S. Weath. Rev.*

Jan. 26.—1^h 33^m, 120th meridian time, a *moderate* earthquake (V) occurred in central California from San Francisco northward to Napa and Petaluma, that is, over a distance of about forty miles north and south. At San Francisco the duration was ten seconds, direction east-west. At San Rafael, time 1^h 38^m, direction east-west. At Oakland, time 1^h 30^m, direction northeast to southwest or west, accompanied by a rumbling noise. The time adopted above is that given by the U. S. Signal Service observer at San Francisco. At 20^h 56^m another lighter shock (IV) was felt in the same district, in regard to which the San Francisco Signal Service observer says: "It began with a slight tremulous motion, which gradually increased in violence and terminated in a quick sharp shock of three seconds' duration."

Jan. 27.—4^h, "a severe and prolonged shock (V ?) was felt at Valparaiso."—*Nature.*

Jan. 30.—21^h 38^m, 120th meridian time, a *very light* shock (III) at Sacramento, Cal., lasting several seconds, direction northeast to southwest.—*U. S. Weath. Rev.*

Jan. 31.—5^h 5^m, a *very light* shock (III), with a rumbling sound like distant thunder, was felt in Cortlandt, Yorktown and other places in the northern part of Westchester County, New York.—*N. Y. Tribune.*

Feb. 2.—7^h 10^m, a very light earthquake (III) was felt at Wytheville, Wythe County, Virginia, with a sound like the rumbling of distant thunder, which seemed to come from the northwest. Apparently it was confined to the immediate vicinity of Wytheville, as inquiries by circular to adjoining counties brought replies from Marion, Smyth County, southwest; Rural Retreat, Wythe County, and Independence, Grayson County, south; Hillsville, Carroll County, southeast; Pulaski Station, Pulaski County, northeast; and Bland Court House, Bland County, north, at none of which places was it felt.

Feb. 3.—0^h 20^m, a rumbling of earthquake at Huntingdon, Quebec.—*Meteorol. Serv. of Canada.*

Feb. 5.—23^h, }
Feb. 6.— 2^h, } Two *moderate* shocks (V ?) at these hours at Geyser Springs, Sonoma County, Cal.—*San Francisco Chronicle.*

Feb. 8.—A telegram from the City of Mexico states that on this date *strong* earthquake shocks (VII ?) were felt at Tequi Sixtlan (?) and Niltepec in the State of Oaxaca, with the fall of one house in the latter place.—*U. S. Weath. Rev.*

Feb. 22.—18^h 53^m, a *very light* shock (III) at Newcastle, Placer County, Cal.—*Sacramento* (*Cal.*) *Bee.*

Feb. 25.—0^h 30^m, a slight rumble of earthquake at Huntingdon, Quebec.—*Meteorol. Serv. of Canada.*

Feb. 26.—The San Francisco Chronicle of this date says: "The earthquakes still continue in the vicinity of Susanville. One shock recently, it is said, shook down the curbing of a well in that town. The shocks appear to be local, as none are felt one hundred miles from here." This locality is in Lassen County in the extreme northeastern part of the State.

March 8.—20^h, a *light* earthquake (IV), with a heavy rumbling sound, was felt in Lancaster, Pennsylvania, shortly after 20^h. Buildings trembled and church services were interrupted.

March 11.—10^h 57^m, two *very light* shocks (III), and at 11^h 7^m a third at St. Johns, Quebec, "in a snow storm;" felt also at Waterloo, Quebec.

March 18.—12^h, a *very light* shock (III) a few minutes past noon at Contoocook, N. H., and vicinity.

March 18.—19^h 45^m, a *very light* shock (III) at Point des Monts, Quebec.—*Meteorol. Serv. of Canada.*

March 23.—20^h 22^m, loud rumbling of *light* earthquake (IV) at Huntingdon, Quebec; "felt all over the country."—*Meteorol. Serv. of Canada.*

March 30.—22^h 34^m, at Mendoza, in the Argentine Republic, occurred three *strong* shocks (VI), lasting about eight seconds. "They consisted in a slow movement of inclination toward the west and a quick return to the east, and for thirty seconds after the last shock a subterranean noise was heard like the rumbling of a distant railway train."—*La Nature.*

March 30.—28^h 56^m, 120th meridian time, a *strong* shock (VI) was felt in central California, extending from San Rafael, Marin County, on the north, to Monterey, Salinas and Hollister on the south. The time stated above is that given by the Signal Service observer at San Francisco, where the direction was east-west. At San Rafael the reported time was 23^h 30^m, and three shocks were felt from the southwest, lasting twelve seconds and sufficiently strong to stop clocks. At San José the reported time was 23^h 35^m, direction east-west. At Salinas and Monterey, at 23^h 45^m, two distinct shocks sufficient to awaken sleepers. At Hollister five distinct shocks during the night, the most severe at midnight, by which several brick buildings were cracked and plaster fell.

March 31.—About 3^h, a *very light* earthquake (III) at Fall Brook, San Diego County, California.—*U. S. Weath. Rev.*

April 2.—7^h 25^m, a *light* shock (IV) at Merced and Fresno, California. A *very light* shock (III) was reported at Sacramento, at 7^h 15^m, which, although somewhat widely separated, may have been part of the same.

April 3.—10^h 15^m, two *very light* shocks (III), northeast to southwest, at Sacramento, California.—*U. S. Weath. Rev.*

April 7.—In southern California a *light* shock (IV) was reported from Bakersfield, Kern County, at 2^h 30^m, direction north-south, with rumbling; and from Santa Barbara and San Buenaventura at 2^h—at the latter place two shocks, direction northeast-southwest.

April 11.—20^h 5^m, 120th meridian time, a *strong* earthquake (VI) was very generally felt in central California. It was felt at numerous places from the coast to the vicinity of the Sierra Nevada, and from Marysville on the north to Monterey and Hanford on the south, with an extension of the boundary toward the southeast so as to include Keeler on Owens Lake, which is east of the Sierra. It was more severe in a tract extending from southwest to northeast across the district above indicated, including Monterey, Salinas, Merced and Stockton. Here it was strong enough to awaken sleepers, to stop clocks, to swing chandeliers, and to cause people to rush from their houses in alarm. At the more distant places, as Marysville, San Rafael, San Francisco, Hanford and Keeler, it was much less strong, being reported as slight, long and slow, very slight, very perceptible, a gentle tremor. The directions reported were: north-south at Ione, Stockton, Merced, Salinas; east-west at Sacramento, San Francisco, San Jose and Monterey, although at Sacramento two observers said north-south; southwest-northeast at San Rafael and northwest-southeast at Keeler. The duration varied from two seconds at Keeler to twenty seconds at San José and San Francisco, and fifteen seconds at Ione, and in several places two shocks were noticed. The one minute and ten seconds duration reported from Merced was probably exaggerated. In the outline of the area of this earthquake given upon the following map, it is quite probable that the eastern boundary would also have been convex if fuller reports had been available from that direction, but that is a much more thinly populated portion of the State, from which there were no reports.

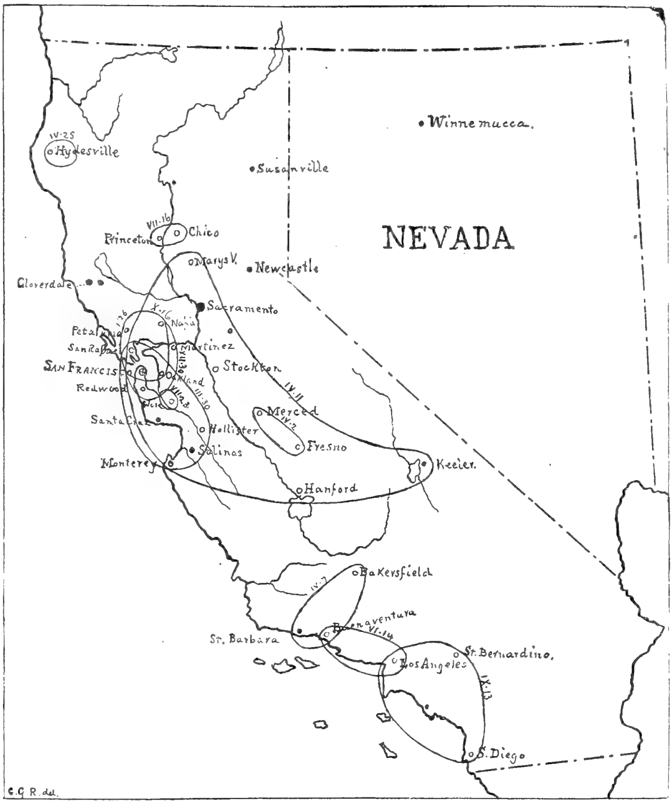
April 13.—19^h 20^m, at Unalashka, Alaska, a *light* shock (IV), lasting only a few seconds, reported by the U. S. Signal Service observer.—*U. S. Weath. Rev.*

April 16.—9^h, at St. Fidèle and Murray Bay, on the lower St. Lawrence, a *light* shock (IV).—*McGill College Obs'y.*

April 18.—Shortly before midnight, exact time not known, a *moderate* shock (V) at Keeler, Inyo County, California, sufficiently severe to disturb sleepers. It was preceded by a loud report as of an explosion.—*U. S. Weath. Rev.*

April 25.—$20^h\ 20^m$, a *very light* shock (III) in Humboldt County, California, reported at Hydesville and Blue Lake.

April 26.—$5^h\ 30^m$, a rumbling of earthquake at Point des Monts, Quebec.—*Meteorol. Serv. of Canada.*



April 28.—$17^h\ 10^m$, a *light* earthquake (IV) at Guilford, Conn., direction east-west, lasting one second.—*New Haven Palladium.*

April 30.—$5^h\ 30^m$, a *very light* shock (III) at Unalashka, Alaska.—*U. S. Weath. Rev.*

May 1.—$21^h\ 30^m$, local time ($24^h\ 21^m$, 75th meridian time), a *light* shock (IV) at Winnemucca, Nevada.—*U. S. Weath. Rev.*

May 3.—About 9^h two *very light* shocks (II) at Dover, Maine. —*J. M. B.*

May 3.—23^h 30^m, local time, a *very light* shock (III) at Olympia, W. T. Light shocks continued until 1^h 30^m of the 4th.—*U. S. Weath. Rev.*

June 14.—3^h 14^m, 120th meridian time, a *moderate* earthquake (V) occurred in southern California, reported at San Buenaventura, Ventura County, and Los Angeles and Cahuenga, Los Angeles County. At the former place two shocks, south to north, were noted, lasting twenty seconds. At the last two places the duration was two or three seconds and direction east-west. It was sufficiently strong to awaken sleepers.

June 25.—20^h 30^m, a *very light* shock (III), north to south, at Salinas, California.—*U. S. Weath. Rev.*

June 27.—5^h 26^m, at Olympia, W. T., a *light* shock (IV), east to west, with rumbling noise.—*U. S. Weath. Rev.*

July 9.—1^h 20^m, at Santa Barbara, California, "five (*moderate*) earthquake shocks (V) occurred between 1^h 20^m and 8^h 15^m, each one of long duration and sufficient severity to awaken the greater number of the inhabitants."—*U. S. Weath. Rev.*

July 9.—A Norwegian bark which sailed northward from Acapulco, Mexico, on this day, reported: "The first day out we felt three distinct earthquakes with thunder and lightning." The distance is too great for this to be identical with the last item.—*Sacramento (Cal.) Bee.*

July 16.—22^h 15^m, a *light* shock (IV) at Princeton, Colusa County, and Chico, Butte County, California. Windows rattled and sleepers were awakened.

July 23.—1^h, at this time began an eruption of Cotopaxi in Ecuador, causing an emission of lava with stones and ashes. The explosions shook the earth to a considerable distance around, rattling doors and windows.—*Nature.*

July 23.—12^h 25^m, a *moderate* earthquake (VI), preceded by rumbling noise, was felt at San José, Santa Clara County, and Centerville, Alameda County, California. At the former place the oscillations were east-west and duration three seconds. Clocks were stopped and slight damage occurred to fragile wares in stores. At Centerville the time was reported 12^h 20^m and direction north-south. A *very light* preliminary shock (III) had been noticed here at about 19^h of the previous evening.

July 31—16^h 10^m, a *strong* earthquake (VII) was felt, north to south, at Cloverdale, Sonoma County, California. The walls in several houses were cracked.—*San Francisco Chronicle.*

Aug. 13.—A *light* earthquake (IV) occurred in the Blue Ridge Mountains in Wautega County, in the northwest corner of North Carolina. It was accompanied by a noise resembling thunder, and was also felt at Boone, ten miles from the mountains.

Aug. 13.—A *light* shock (IV) was felt at St. Kitts, West Indies. —*N. Y. Tribune.*

Aug. 14.—$23^h\ 5^m$, a *very light* shock (II) at Garrettsville, Portage County, Ohio.—*U. S. Weath. Rev.*

Aug. 19.—A *moderate* shock (V) at Valparaiso, Chili.—*N. Y. Times.*

Aug. 30.—*Light* shocks (IV) felt at Jamaica, W. I., in the evening.—*N. Y. Tribune.*

Sept. 4.—$9^h\ 40^m$, a *light* shock (IV) was felt in the villages of Campbellford, Hastings and Norwood, Ontario.—*U. S. Weath. Rev.*

Sept. 13.—$4^h\ 34^m$, a *light* shock (IV) in southern California. It was felt along the coast from Los Angeles to San Diego and inland to San Bernardino. At Los Angeles the direction was given as southwest to northeast; at San Diego, where two shocks were felt, lasting in all twelve seconds, the direction was east-west; at Murrietta it was the same and three shocks were reported; at Cahuenga it was northwest-southeast and duration about three seconds. The time stated above is that reported by the U. S. Signal Service observer at San Diego, reports at other stations vaguely given varied from 4^h to 5^h.

Sept. 26.—16^h, reports of earthquake at this time in Washington County, Pennsylvania, were due to the passage of a meteorite and not to any terrestrial disturbance.

Oct. 9.—8^h, a *moderate* shock (V), south to north, at Olympia, W. T.

Oct. 9.—$23^h\ 36^m$, a *moderate* earthquake (V) was felt in Virginia. It was more severe at Lynchburg, Campbell County, and Staunton, Augusta County, and vicinity, where windows and furniture were shaken and some persons ran out of their houses in alarm. It was felt also at Petersburg, where many were waked by shaking windows; very slightly at Richmond; and by one person, at $23^h\ 42^m$ in Washington, D. C. In the latter place it was not noticed at the Signal Service office, nor at the Naval Observatory, and left no trace on the records of the self-registering barometers. At Lynchburg the direction was north-south, and both here and at Variety Mills in Nelson County, a second shock occurred about an hour later.

Oct. 10.—Between 1^h and 2^h three *very light* shocks (III), each of about one second duration and separated by an interval of six seconds, at East Portland, Oregon.—*U. S. Weath. Rev.*

Oct. 11.—In the evening a *destructive* earthquake (IX) occurred throughout the Republic of Nicaragua. It was felt at San José at $22^h\ 30^m$. The following account is given by Earl Flint, M.D., of Rivas.

"The earthquake was more prolonged than that which was felt at Chinendega in 1851. The shock was general throughout western Nicaragua. it was also felt to the eastern part of the axial line, beyond the lake, and along the eastern slope of the main Cordilleras, although it was less severe in that region. Reports from prefects give the greatest force at Leon, Old Chinendega and Managua. Leon cathedral was fractured in various places; Laborio church tower was telescoped, and other churches were injured. The government house, barracks, seminary, Institute. and bishop's palace were also damaged, and most of the adobe houses lost partition walls. Managua and Chinendega suffered similar losses, though somewhat less. The shock began with a slight and prolonged oscillation northwest and southeast, and its duration allowed most of the people to reach the streets and yards; but those who had retired, being delayed in opening doors, were bruised by the falling tiles and partition walls. Five deaths occurred at Leon and one at Managua."—*U. S. Weath. Rev.*

Oct. 16.—$4^h\ 45^m$, 120th meridian time,—a *light* earthquake (IV) occurred in central California, being very faint at San Francisco, light at San Rafael and heavier at Napa and Santa Rosa. At Napa the direction was north-south and a slight preliminary shock was felt at midnight. At Santa Rosa three shocks were noted, direction northeast-southwest. Almost exactly the same region had been shaken on January 26.

Oct. 17.—$17^h\ 30^m$, a *light* earthquake (IV) occurred at Sandersville, Washington County, Georgia.

Oct. 26.—Between 1^h and 2^h two *very light* shocks (III) at Frisco, Utah, each lasting about two seconds and accompanied by a rumbling noise.—*U. S. Weath. Rev.*

Nov. 11.—$11^h\ 58^m$, a *very light* earthquake (III) at Helena, Montana, of about three seconds duration.—*U. S. Weath. Rev.*

Nov. 19.—Between 13^h and 20^h earthquake waves were indicated on the coast survey tide-gauge at San Francisco. "They were thirty-five minutes apart and were as great as those observed during the great upheaval in Java some years since."—*Nature.*

Dec. 7.—22^h, at Quamichan, B. C., an earthquake (IV) reported by the observer of the Meteorol. Serv. of Canada.

Dec. 8.—In the evening a *moderate* earthquake (V) occurred in the vicinity of Puget Sound, W. T. The principal shock occurred at $22^h\ 40^m$, 120th meridian time, and was felt as far south as Olympia, where the motion was east-west and was sufficient to arouse sleepers. At East Sound three light shocks were reported at $22^h\ 35^m$; two heavy ones, rattling dishes at $22^h\ 40^m$; two light ones at $23^h\ 15^m$, and a somewhat heavier one at $23^h\ 50^m$. At Victoria, B. C., the time given was $22^h\ 12^m$ (local time ?), a loud rumbling was heard and the duration was ten or fifteen seconds. It was also reported from Port Angeles and Salt Springs Island.

Dec. 11.—$2^h\ 4^m$, a *moderate* earthquake (V) occurred in Chili and Peru. It was reported from Valparaiso, Arica, Taena and Serena, but was most seriously felt at Iquique where buildings were shaken. Five minutes after the first shock a second slight shock followed, and after another ten minutes a third was felt, which was followed later by two more slight shocks. The sea was extraordinarily agitated and the agitation continued with diminishing intensity through the 12th.

Dec. 18.—0^h 30^m, a *very light* shock (III) at Tatoosh Island in the extreme northwest of Washington Territory. It lasted about five seconds and was followed by a second shock about ten minutes later.—*U. S. Weath. Rev.*

Dec. 18.—At Amatitlan, Guatemala, a place of about 5,000 inhabitants, situated twenty-four miles south of the city of Guatemala, slight but frequent earthquakes occurred, continuing all day from 2^h to 17^h 22^m when a heavy shock was felt. At 17^h 36^m the heaviest and most *destructive* shock (IX) came, throwing down many walls and houses already fissured by the earlier shocks; people were thrown down and the air was filled with the dust from the fallen adobe houses. One hundred and thirty-one shocks were felt the first day, principally from east to west, eighty-one of which occurred between 16^h and 17^h 36^m. The second day was nearly as bad, and the shocks continued for some days subsequent. A government commission, consisting of Professor Rockstroh and Mr. Walker, visited the place and reported the total destruction of the village of San Vincente Pacaya and an increase in the amount and temperature of the water emitted by the hot springs about Lake Amatitlan, but no increased activity in the volcano of Pacaya.

Dec. 28.—Between 3^h and 4^h, at Santa Cruz, California, two *light* shocks of earthquake (IV); the vibrations were north and south.—*U. S. Weath. Rev.*

Dec. 28.—19^h 5^m, a loud explosion accompanied by a rumbling sound and a *very light* earthquake shock (III) occurred at Bloomington, Illinois.

Dec. 29. Between 4^h 30^m and 5^h 30^m some *very light* shocks (III) were reported at Hartford, Connecticut.

Dec. 30.—9^h 46^m, a *moderate* earthquake (V) was felt in the vicinity of the bay of San Francisco. It extended from Redwood City and San Mateo on the south, to Napa and Petaluma on the north, and inland to Port Costa and Martinez, Contra Costa County. At San Francisco it was preceded by a very light shock, and the main shock lasted ten seconds with a north-south motion, but here it was not very generally noticed by people in the open air. At Oakland the duration was six seconds, motion east-west, with a rumbling noise. At San Rafael houses rocked and a loud noise was heard. At Petaluma and at Redwood City the direction was north-south. This is the third earthquake in this same district during the year; the others were on January 26 and October 16.

The above list for 1885 contains 71 items, not counting the one of Sept. 26, of which five are in small type. They may be geographically classified thus:

Canadian Provinces	8
New England	5
Atlantic States	9
Mississippi Valley	3
Pacific Coast of U. S.	34
Alaska	2
Mexico	1
Central America	2
West Indies	2
Ecuador	1
Peru and Chili	3
Argentine Republic	1
	71

By seasons they are classified thus: Winter, 24 (Dec. 8; Jan. 9; Feb. 7); Spring, 22 (Mar. 8; Apr. 11; May 3); Summer, 14 (June 3; July 6; Aug. 5); Autumn, 11 (Sept. 2; Oct. 7; Nov. 2); Spring and Summer together, 36; Autumn and Winter together, 35.

Those estimated as having an intensity of VI or over, on the Rossi-Forel scale, were as follows:

VI. March 30, Argentine Republic; March 30, April 11, July 23, California.

VII. February 8, Mexico; July 31, California.

IX. October 11, Nicaragua; December 18, Guatemala.

The last two were the only ones in which serious injury to buildings or loss of life was reported.

So large a proportion of the earthquakes of the year have occurred in California, that I have added (p. 12) an earthquake map of that State for 1885, from which it will be seen that the bay of San Francisco is situated in a particularly shaky region. The greater number of earthquakes which are reported here may be in part due to the better facilities for collecting data, as this is the most thickly settled part of the State, but it can hardly be attributed to that cause alone. Upon the map the area of each earthquake is enclosed by a line upon some part of which the date is given. The black dots represent shocks which were reported from one place only. At Sacramento this occurred twice in the year. The map will also show what parts of the State were shaken more than once; thus San Francisco and San Rafael were within the areas of five distinct earthquakes.

I append a list of earthquakes in 1883 and 1884, which have come to my knowledge since the reports for those years were printed. None of them call for special comment.

1883.

Nov. 25.—Hour not stated, an earthquake of seven or eight seconds with subterranean noise was felt at Curaçoa, Coro, Maracaibo and Churuguara, Venezuela, repeated on the 26th.—*L'Astronomie.*

1884.

The following earthquake notes from South America are taken from a list of earthquakes published by M. C. Detaille in L'Astronomie, 1885 (p. 183). Most of the reports are from Valparaiso, and when no place is stated Valparaiso is to be understood.

Jan. 1.—3^h 10^m, a strong shock at Valparaiso with subterranean noise.

Jan. 5.—15^h, a long shock.

Jan. 7.—3^h 8^m, three distinct shocks each continuing some seconds. 20^h 18^m, a strong shock but of short duration.

Jan. 14.—13^h 15^m, a sharp double shock was felt in Jamaica. At Kingston the first shock lasted about three seconds and was followed after an interval of two seconds by a second shock lasting about five seconds. It was felt over nearly the whole of the island.—*Nature.*

Feb. 5.—3^h, a strong shock at Valparaiso.

Feb. 8—9^h 30^m, a rather strong shock.

Feb. 9.—5^h 30^m, a strong shock.

Feb. 14.—3^h 30^m, a strong shock.

Mar. 3.—3^h 35^m, a strong shock.

Mar. 13.— 23^h 25^m, a strong shock.

Mar. 14.—23^h, a strong shock.

Mar. 22.—17^h 15^m, a strong shock.

Mar. 23.—4^h, two shocks; another at 17^h.

Mar. 24.—4^h, a weak shock.

Mar. 25.—5^h, a rather strong shock.

Mar. 28.—16^h, a very strong shock.

April 9.—3^h 45^m, two strong shocks.

April 11.—2^h 15^m, rumbling and strong shock.

April 14.—7^h 15^m, feeble shock.

April 15.—3^h 30^m, a strong shock followed by two less strong.

April 18.—22^h 50^m, a strong and prolonged shock with thunder, duration 30 seconds.

April 25.—7^h 15^m, strong shock coming from the south, preceded by a subterranean noise.

April 29.—4^h 15^m, three very light shocks.

May 3.—15^h 40^m, very long and strong shock.

May 5.—17^h 15^m, light shock.

May 8.—18^h 10^m, feeble shock. 19^h 44^m, very strong and vertical shock.

May 13.—3^h 45^m, a very strong and very prolonged shock.

May 14.—6^h 30^m, very long trembling without great shock.

July 4.—4^h 20^m, at Ponso Alegre, Brazil, a village about 200 miles west of Rio Janeiro, a shock from north to south of some seconds duration.

July 6.—8^h 15^m, at Valparaiso, a strong short shock preceded by a rumbling.

July 9.—0^h 15^m, a very long shock, not very strong.

July 15.—12^h, two short but rather strong shocks.

July 18.—5^h, at Nicaragua, a strong shock; also at 8^h with subterranean noise.

July 18.—22^h 30^m, a very long continuous shock lasting about one minute at Valparaiso.

July 19.—7^h and 8^h, shocks at Nicaragua.

July 29.—6^h, a shock at Nicaragua.

Aug. 15.—A shock was felt at sea on the ship "Charles Dennis" in lat. 17° N. long. 75′ W. This position is in the Caribbean Sea about 100 miles southeast of Jamaica.

Sept. 25.—16^h 6^m, at Iquique, Peru, a strong and prolonged earthquake, south to north, duration 35 to 40 seconds. The bells in the cathedral were rung and the cross had a decided motion.

Oct. 6.—0^h 45^m, at Valparaiso, a very long and very strong shock somewhat dangerous.

Oct. —.—Several shocks at the end of October.

Nov. 6.—Capt. James Cooper of the ship "Struan," reports two shocks (IV) direction southeast to northwest, duration thirty seconds and twenty seconds respectively, with an interval of about one minute between them, in lat. 4° 17′ N.; long. 79° 40′ W., which is in the Pacific Ocean, about 100 miles from the coast of Colombia. This was probably connected with the earthquake on this date in Colombia, mentioned in the last "Notes." (Am. Jour. Sc. xxix, 435.)—*U. S. Weath. Rev.*

Nov. —.—At Valparaiso, "numerous shocks all the month of November."

Princeton, N. J., April 13, 1886.

ART. III.—*Observations on the Tertiary and Grand Gulf of Mississippi;* by OTTO MEYER, Ph.D.

I HAVE spent some time recently in Mississippi, mainly for the purpose of determining the relative positions of the Marine Tertiary and the Grand Gulf formations in the State. Through part of my journey, that is, from Jackson to Terry and from Pelahatchee to Brandon, I had the company of Mr. T. H. Aldrich, and I am greatly indebted to him for calling my attention to the places in Mississippi which might yield me information.

The natural valleys which probably give the best information about the stratification in Mississippi are those of Pearl River and the Chickasawhay at their lowest water level. At the time of my visit, however, the water was too high for such an exploration, and the only means for determining the contact of the Grand Gulf and Tertiary seemed to be systematic examination of the railroads near the frontier of the two formations.

1. Along the railroad south of Vicksburg, the Vicksburgian, covered by Loess, can be traced along for about a mile; then the Loess seems to cover everything.

2. The railroad from Jackson to Natchez has a narrow gauge, and between Jackson and Raymond shows no deep cuts. In Raymond a clayey sand is to be seen.

3. On the railroad from Jackson to New Orleans we find Tertiary limestone alternating with softer strata one mile north of Byram station, all containing Orbitoides and Pecten. In Byram occurs marl with Vicksburgian fossils. Five and a half miles south of it, that is, half a mile north of Terry, on the creek at the iron railroad bridge, the first sure outcrop of Grand Gulf is found.

The following profile of the Grand Gulf strata north of Terry was taken by Mr. Aldrich and myself:

(*c*) Light sandy clay	10 feet
(*b*) Sandstone, hard above, softer below, containing small nodules of green clay or corresponding cavities	7 feet
(*a*) Green sandy clays	5 feet to water's edge

Three and a half miles south of Terry, a deep cut about 1,400 feet long, shows a remarkable exposure of Grand Gulf strata. They are laminated sandy clays and clayey sands. The fine lamination of the clays is made very conspicuous wherever water runs over them. Laminæ of iron concretions also make the stratification more conspicuous. The northern two-thirds of the cut shows a very strong northern dip, abruptly turning over southward in the remaining third with an equally strong dip. The height of the cut at the anticlinal is twenty-five feet, twenty feet of it composed of these clays. Taking the dip into consideration the total thickness shown is about forty feet. Small pieces of lignite are disseminated through the layer, but no fossils were found by Mr. Aldrich and myself. Not only the general dip of the strata in this cut, as mentioned, changes suddenly, but besides this, the *stratification shows cross-bedding.*[*] Between this cut and Terry ledges of white Grand Gulf sandstone, several feet thick, crop out at different places.

In recapitulation we have Vicksburgian strata occurring in Byram station and Grand Gulf strata occurring about five miles south of it, but the contact of the two formations cannot be observed along the railroad.

4. On the railroad from Meridian to New Orleans the Marine Tertiary reaches at least as far as Heidelberg, Jasper County, for there is blue limestone, from which I collected *Orbitoides* and *Pecten Poulsoni* in an abandoned quarry about one mile and a half southeast of this town. Walking along the railroad we meet a clay of a light greenish blue color at a point four miles south of Heidelberg. At a point eleven miles south of this town (south of Erata, Jones County) the railroad cuts about ten feet of gray sandy clays and white sands without fossils.

5. In Pelahatchee on the Vicksburg & Meridian Railroad we find Marine Tertiary clays with *Pecten calvatus?* Mort., *Scalaria sp.*, teeth of sharks and *Miliobates*, vertebra of fish and clayey concretions containing casts of shells, especially of *Protocardia*. Three miles west of it we meet the first cut of Grand Gulf strata—laminated clays—but the contact of the two formations cannot be observed here.

6. Walking farther west from the just mentioned cut of the Grand Gulf clays toward Brandon, we meet another exposure of these laminated clays a mile distant. They have a thickness of more than twenty feet and *show a very strong westward dip.* Another mile farther on, the same strata, of about equal thickness, are nearly horizontal. Another exposure is met about one mile and a half still farther west. It consists of laminated clays of about eighteen feet thickness, containing impressions of leaves. Sometimes the beds are more sandy, and in a few places they show cross-bedding. These clays are here enclosed in two lignitic streaks. The lower streak consists of almost pure lignite. Below this lower lignitic streak there are seen gray clayey sands without visible stratification. These sands at this point were not examined as to whether they contain fossils or not. The dip in this exposure, which consists of two connecting cuts, is west. The next cut is about a mile

[*] Discordante Parallelstructur.

farther west. It contains the same laminated clays with cross-bedding and at the bottom the gray clayey sands of the preceding cut are seen. They were here examined and found to contain extremely friable casts of small bivalves, apparently marine. Near the top of the laminated clays there is a streak of kaolin.—*This whole material of about twenty feet thickness is overlaid by a strip of limestone containing Pecten Poulsoni, Orbitoides, etc.* A dip in this cut is not apparent. Going farther toward Brandon no sure Grand Gulf strata were seen, but outcrops of limestone occur at two or three points at the same height with, or somewhat higher than the railroad track. Approaching Brandon and about half a mile from the station marine strata of about fifteen feet thickness are seen. They consist of sands overlaid and underlaid by ledges of limestone, all the beds containing *Pecten Poulsoni* and *Orbitoides.* The sands are sometimes clayey and at one place there are among them stratified clays of a few feet thickness which are not laminated, and contain on the planes of stratification shells and shell detritus. At Brandon station the limestone and patches of the sands are seen; and going west of the station hard limestone ledges, alternating with softer material, containing Pecten and Orbitoides occur as far as two miles west from Brandon.

The relation of the heights of all the above-mentioned cuts is as follows: The railroad track rises from the point two miles west of Brandon toward Brandon, continues to rise to the point where the contact of the Grand Gulf and marine limestone can be seen (about four miles east of Brandon); continues farther to rise for some distance in the Grand Gulf region and then falls down toward Pelahatchee.

Recapitulating these observations: Between Pelahatchee and Brandon the railroad cuts through, for a length of five miles, a belt of Grand Gulf strata, which are situated at a higher level than the marine strata west of it and which are either nearly horizontal or strongly dipping west. The Marine Tertiary of Brandon rises toward these Grand Gulf strata, and at the point where the two formations meet the marine limestone has a thickness of only two feet and overlies the Grand Gulf clays.

Those geologists who object to the conclusion from this that the Grand Gulf is older than the Marine Tertiary have the choice between two hypotheses. They can either consider this whole region of laminated clays, lignite, etc., with this peculiar dip, as not belonging to the Grand Gulf formation, or they can consider all these exposures as Grand Gulf with the only exception of that one where the orbitoidic limestone is seen on the top. After a careful examination of this region I am unable to share in either of these hypotheses.

7. In Newton, Newton County, at the Vicksburg & Meridian Railroad, laminated clays dipping east, apparently belonging to the Grand Gulf formation, may be seen. Three miles east of Newton there is a vertical railroad cut two hundred feet long and about fifty feet high affording the following profile:

(*c*) Clayey green sands of varying quality, sometimes with hard ledge-like nodules, numerous well preserved fossils; nearly	40 feet
(*b*) Reddish sand, somewhat lignitic	4 feet
(*a*) *Laminated clays, cross-bedded* with pockets of sand. They either alternate with or are overlaid by lignitic sandy clays or clayey sands, scarcely stratified, *with numerous lignitized plants and roots erect in natural position*	10 feet

The stratum "*c*" is seen on the surface 1,000 feet west from the cut on the railroad track, and therefore the dip must be west. I collected in this stratum "*c*," in less than a day, 105 species of fossils. The position of the lignitized plants in the stratum "*a*" shows that they grew on the spot, apparently in very shallow water (swamp?).

The above is the account of my efforts at eight different points to find the contact of the Grand Gulf beds and the Tertiary. The following observations are less directly connected with this question.

Greensands south of Enterprise.

The same clayey greensands, mentioned above, from Newton (stratum "*c*") occur in cuts of the railroad between Meridian and New Orleans, four miles south of Enterprise near Wautubbee, and are here underlaid by white, micaceous, cross-bedded sands, which attain a thickness of at least twenty feet and sometimes contain clays. These greensands are here very variable in thickness and in petrographic and paleontological qualities. Sometimes they are clayey, sometimes stratified, hardened and lignitic. At one point occurs the same ledge-like nodules as in Newton, containing *Ostrea sellæformis* C. I collected here 110 species, agreeing mostly, although not entirely, with those in Newton, among them two species of Cephalopods. The description of this Wautubbee-Newton fauna will appear in the Journal of the Cincinnati Society of Natural History for July, 1886. If I am not mistaken the same bed occurs at the tunnel west of Meridian and I think it is identical with a greensand bed which can be seen on the Chickasawhay at the bridge in Enterprise, underlying my bed "*b*"* (Claiborne profile). If this is so, the bed ranges stratigraphi-

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* See this Journal, xxx, pp. 69, 70, 71, 1885.

cally immediately below the Claiborne profile and the paleontological evidence points to the same result and shows it to be parallel with the strata in Lisbon, Ala. After this position is determined it will be of interest in regard to the age of the Jacksonian to notice that the following species of this fauna occur in Jackson and are not known from the Claiborne sand: *Arca aspera* C., *Leda multilineata* C., *Pecten scintillatus* C., *Mitra pactilis* C. *var. dumosa* C., *Distortrix septemdentata* Gabb, *Solarium bellastriatum* C., *Flabellum Wailesii* C.*;* and the following species are known only from the Vicksburgian: *Corbula engonata* C., *Chama Mississippiensis* C., *Caricella reticulata* Aldr.

Profile of the strata in Jackson.

The profile of the strata near Jackson, taken by Mr. Aldrich and myself at various points, is as follows:

(*f*) Clay; blue below, lighter above, containing a large number of small bivalves, *Kelliella ?*, *Corbula*, *Leda* and crab-claws. The shells are either very thin and soft or entirely dissolved, leaving only a few impressions	20–25 feet
(*e*) Glauconitic marl, varying in distinctness, containing Pecten, various Bryozoa and corals, concretion-like Madrepora (nigger-heads), all in abundance, and in addition to them some Jacksonian fossils, about	2 feet
(*d*) Jacksonian shell marl. Yellowish; or yellowish above and blue below. At one point this subdivision of this stratum is marked by a layer of *Rostellaria* in great quantity	10–15 feet
(*c*) Dark lignitic clay, without fossils at some points, but at others containing pockets of green sand full of Jacksonian fossils, bivalves numerous about	5 feet
(*b*) Earthy lignite	20 inches
(*a*) Gray sandy micaceous clay	———

It will be seen that this profile differs from a profile given by Mr. D. W. Langdon* in that he puts strata "*e*" and "*f*" together. About a mile south of Jackson clays occur, which may be or may not be identical with the clays in "*f*." Mr. Langdon observes clays on the river south of Jackson only a few feet above the water, but not far from the river clays are to be found at heights of more than fifty feet above the river level. I have little doubt that the lignitic, non-fossiliferous stratum with very strong dip between Jackson and Byram will be found on examination underlying the Jacksonian as well as the Vicksburgian.

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* This Journal, xxxi, p. 202, 1886.

The Jacksonian stratum "*d*" occurs at Moody's Branch at a higher level than southeast from there at the bridge over the Pearl River. This would indicate a southern dip. On the other hand, following Moody's Branch toward its mouth in a southeastern direction the older strata dip up stream. Stratum "*e*" is seen at the uppermost part of the creek two feet above the water; a few hundred yards below, its surface is five feet above the water, and farther below, the whole stratum is about four feet above the water. Supposing a difference in the water level of four feet even, which must be a maximum there, there is yet a northern dip for these strata at this creek.

Grand Gulf formation in Grand Gulf.

The material of the Grand Gulf formation in Grand Gulf is quite variable. Cross-bedded sands pass over and alternate with friable as well as hard sandstones of the same structure and even regular quartzites occur. The clays have different degrees of induration. I did not notice here the laminated clays found in Terry. It may be that these laminated clays occupy the highest horizon of the Grand Gulf formation, above the sandstones which form the top of the strata in Grand Gulf —if the "Grand Gulf formation" is one single formation.

The sandstones enclose silicified trees. Although making a careful search I was unable to detect any shells as such in these strata, but some of the indurated clays, besides traces of lignitized plants, *contain impressions of fresh-water bivalves*, and these cannot be said to be very rare. The most distinct ones which I was able to collect are two casts of *Unio*, each showing both valves. I procured in all casts of at least three species of *Unio.*

Resumé.

1. After studying the literature as well as the field, I do not know any place where Grand Gulf strata can be seen in actual superposition over the Marine Tertiary.
2. There are two places where strata which cannot be distinguished from unquestioned Grand Gulf can be seen actually overlaid by Marine Tertiary. In one of the cases, moreover, there is internal evidence that these strata were dry land or nearly dry land before the Marine Tertiary was deposited upon them.
3. The Grand Gulf formation, at least for its main part, is not a marine formation; it contains fresh-water shells.
4. A thick and extended marine greensand formation with a numerous fauna is found in Eastern Mississippi. It is parallel to the strata immediately below the Claiborne profile. Its fauna is Claibornian, but approaches the Jacksonian.

ART. IV.—*Notes on the Volcanic Rocks of the Republic of Salvador, Centrál America;* by ARNOLD HAGUE and JOSEPH P. IDDINGS, of the U. S. Geological Survey.

MR. W. A. GOODYEAR, for a long time in the employ of the government of the Republic of Salvador, Central America, as mining engineer and geologist, has recently sent us for examination and comparison a small but interesting collection of volcanic rocks, gathered by himself in the course of his explorations in that country.

Salvador is the smallest of the Central American Republics. It stretches along the shore of the Pacific from the Gulf of Fonseca to the border of Guatemala. Fifteen miles inland from the coast the mountains rise abruptly above the plain, presenting a chain of volcanoes at irregular intervals with a trend about north-78°-west approximately parallel with the ocean. The principal volcanoes in the republic are Apaneca, Izalco, San Salvador, Santa Ana, San Vicente, San Miguel, and Tecapa. None of them reach any great altitude above sea-level, but many have been more or less active within historic times, while the now famous volcano of Izalco has been wholly built up since the occupation of the country by Europeans. Between these isolated cones and to the northward stretch broad table-lands largely made up of volcanic materials cut through by streams running to the ocean. The broad, general features of these volcanoes and their relations to the physical geography of Salvador, have been described with some detail by travelers who have from time to time explored the country. Notably among these may be mentioned geologists Dollfus and Mont-Serrat, who visited Central America by order of the French government in 1864, and published upon their return, in an elaborate volume, the results of their expedition.*

The vast accumulation of volcanic rocks, lavas, pumices and ashes poured out in Central America appear to have been very little investigated by modern methods of research. A few notes, therefore, which we are able to offer may not be without value to those interested in the lithology of volcanic eruptions.

The specimens collected represent recent volcanic flows, the summits of craters, the slopes of the more important volcanoes, the bottom of deep cañons, table lands, mining districts and quarries. While the collection contains no suite from any one locality showing the relations between different varieties of rocks, it is sufficiently full to be considered as typical of the eruptive rocks of the country.

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* Voyage dans Guatemala et Salvador. Paris, 1868.

In the collection are rocks showing a wide variation in mineral composition ranging from very basic to highly acidic forms, from those rich in olivine to others carrying an abundance of quartz. They can all be classified under the following heads: basalt, pyroxene-andesite, hornblende-pyroxene-andsite, hornblende-mica-andesite, dacite and possibly rhyolite. Basalt and dacite are better represented in the collection than the other types. Typical hornblende-andesite, augite-andesite and rhyolite are not found among the specimens studied, and the hornblende-mica-andesites are closely connected with the dacite by the presence of small amounts of porphyritic quartz.

Basalt.—These rocks present quite a variety of forms, differing in compactness from dense to vesicular and scoriaceous, from glassy to crystalline. In color they vary from black to dark-gray, sometimes mottled and red. Some are crowded with small porphyritic crystals of feldspar and olivine, while others are nearly free from macroscopic crystals. The same variableness is observed in thin sections, though the majority of the specimens show a fine-grained groundmass, either glassy and microlitic or microcrystalline, composed of plagioclase, augite and magnetite. Glass, when present, is either colorless or brown and globulitic, occasionally the base of the groundmass is quite opaque from the abundant particles of iron oxide which crowd it. The porphyritic crystals which vary in actual and relative amounts are: basic plagioclase, olivine, augite, magnetite and sometimes hypersthene. The plagioclase, which fills many of the basalts in small porphyritic crystals, appears to be of the more basic species and carries much glass and groundmass in minute inclusions. These feldspars specially characterize the basalt thrown out from San Miguel on January 25, 1884, the most important eruption from this volcano in modern times. Since then the volcano has been comparatively quiet, though every year giving signs of activity more or less intense. Similar feldspars occur in the basalt erupted from the crater of Izalco, January 1, 1881. In both rocks the feldspar crystals average 2^{mm} in length. Olivine is in more or less well developed individuals of small size and of the usual form. It occurs in all stages of decomposition, from fresh to wholly decomposed. In most of the specimens it is quite abundant, but decreases gradually to those in which only an occasional individual is found, hypersthene at the same time increasing in amount where the rock is porphyritic, noticeably in the region of Sensuntepeque.

Augite, in imperfect crystals and grains, is much less abundant among the porphyritic crystals than as a constituent of the groundmass. It is pale, yellowish green in thin section, and the larger individuals occasionally enclose olivine besides the usual inclusions of glass and magnetite. A rhombic pyroxene of light brown color in thin section, with marked pleochroism, green parallel to the *c* axis and light reddish brown at right angles to it, has the same microscopical character as that found in many andesites in the Great Basin and Pacific coast volcanoes, which chemical analysis has shown to be a variety of hypersthene. It is only found in those basalts poor in olivine. Small crystals and irregular grains of magnetite are always present.

The general structure of these basalts is porphyritic, with the porphyritic crystals in greater or less amounts, usually the feldspars are more abundant than the other macroscopic constituents, though in a few instances the olivine is the most prominent. Only in one of the basalts is there an approach to granular structure, and this occurs on the summit of the crater San Miguel; at the same locality also occur several of the most porphyritic and fine-grained varieties.

Pyroxene-Andesite.—These rocks are represented by fewer specimens than the basalts and in general are not in as fresh a condition. They are dark colored rocks, with many small porphyritic feldspars, 2 or 3^{mm} long, and fewer macroscopic pyroxenes. Eighteen thin sections show that in almost every case there is a very fine-grained, holocrystalline groundmass of feldspar, pyroxene and magnetite grains, with a greater or less amount of porphyritic crystals, of which plagioclase is the most abundant. The pyroxene is only in a few instances entirely fresh. In these cases it is seen to be of two varieties, a light green augite and a pleochroic, pale brown, orthorhombic form, which, as already remarked, corresponds in all its microscopical characters to the hypersthene of the Great Basin rocks. The rock from Cerro de Cunchique is a pyroxene-andesite with small amount of olivine; one of the intermediate forms between these andesites and basalt.

Hornblende-Pyroxene-Andesite.—This is represented in the collection by still fewer specimens, mostly pumiceous in character. They are glassy, fresh rocks with porphyritic crystals of feldspar, hornblende and pyroxene. In one specimen from San Sebastian quarry there occur a few scattered grains of crackled quartz, and in rock from the volcano of Ilopango occasional grains of olivine. No mica was observed either in the hand specimens or in thin sections.

The porphyritic feldspars are all plagioclase, apparently in the labradorite-andesine series, with numerous inclusions and other features characteristic of the feldspars of glassy andesite. The hornblende is of a brown color, in some cases with a reddish, in others with a greenish tinge. It is without black border, and in not perfectly developed crystals. The margins of the larger hornblendes are often filled with grains of pyroxene. The pyroxene, which is less abundant than hornblende, consists of a pleochroic, orthorhombic and a green, monoclinic variety, the former being in excess. Magnetite appears as a regular porphyritic constituent.

The groundmass of the pumiceous varieties is a colorless glass with a few microlites. A holocrystalline form was collected at San Francisco Mercedes.

The most notable occurrence of hornblende-pyroxene-andesite is the rock of the new volcano which first made its appearance above the water in the center of Lake Ilopango on the morning of January 21, 1880. Lake Ilopango measures between nine and ten miles in length, is very irregular in width, presenting about forty square miles of surface. It lies about five miles due east of the City of San Salvador and about 1500 feet above sea-level. Mr. Goodyear, who had been studying the very remarkable series of earthquakes which occurred all over Salvador in December of the preceding year, recorded over six hundred earthquake shocks, all of them sufficiently severe to be perceptible without the use of instruments. On the day following the first eruption Mr. Goodyear* visited the young volcano and brought away with him a piece of the rock still hot from the steam issuing from the numerous vents.

The breaking out of this volcano was generally regarded by the people of San Salvador as having saved the city from a serious calamity.

The rock is a gray pumiceous glass, full of brilliant feldspars, 4 or 5^{mm} and less in length, and numerous small crystals of hornblende with hypersthene and augite, and occasionally a grain of olivine. It is worthy of mention that within a short distance from this outburst of hornblende-pyroxene-andesite, and within twelve months of the time, the volcano Izalco threw out basalt from the crater.

Hornblende-Mica-Andesite.—This type is poorly shown in the collection, only three localities in the Republic being represented. They carry beside the porphyritic crystals of plagioclase, hornblende, hypersthene, and a little augite, variable amounts of brown mica and quartz, and in this way form a transition to the dacites. They resemble some varieties of the hornblende-mica-andesites found at Washoe, Nevada.

Dacite.—Rocks of this type are found in numerous localities throughout Salvador, and present quite a variety of forms. They are mostly light colored in shades of gray and purple, and frequently unite characters both of andesite and rhyolite.

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* W. A. Goodyear: Earthquake and Volcanic Phenomena, December, 1879 and January 1880, in the republic of Salvador. Panama, 1880.

Those, characterized by large porphyritic crystals of feldspar and quartz with much mica and hornblende, approach the hornblende-mica-andesites, while those poor in the iron-magnesian silicates closely resemble the rhyolites. In thin section it is seen that the feldspars of those rocks rich in porphyritic crystals are almost wholly triclinic, scarcely an orthotomic feldspar having been recognized among them. The species probably belong to the andesin-oligoclase series. Porphyritic quartz is at the same time abundant in dihexahedral crystals or rounded grains, bearing glass inclusions, frequently with the accompanying phenomena of strain. Biotite occurs in excess of the hornblende, which is often entirely absent. The different varieties of these dacites have their equivalents throughout the Great Basin of Utah and Nevada, especially at Mount Prometheus in the Toyabe Range, and in the Eureka and Washoe mining districts. No well defined rhyolites with characteristic sanidin are found in this suite of rocks, although chemical analysis might possibly show that some of the lithoidal varieties without any well defined mineral constituents more properly belong to rhyolite than dacite.

An examination of this collection shows clearly that the vast accumulation of material poured forth from the volcanoes of the Cordillera of Salvador bears the closest resemblance in composition to the lavas from the volcanoes of the northern Cordillera in California, Oregon, and Washington Territory, notably Mount Shasta, Lassen's Peak, Mount Hood and Mount Ranier.

Moreover a rigid comparative study of these rocks proves clearly the closest similarity between the volcanic lavas of Salvador and those of the Great Basin of Utah and Nevada, both as to macroscopical habitus and microscopical detail. In comparing rocks of corresponding types from the two regions they are seen to carry the same constituent minerals with identical characters in thin section, and the same gradation in mineral composition. Transition rocks from one well-defined type into the next more or less basic or acidic type are sufficiently well represented in Salvador to show the same laws of mineral development as observed in the lavas of the Great Basin.

It is interesting to note that nearly every rock in this collection has its counterpart in Nevada, although there occur many varieties in the latter region not found in the limited series from Central America. This is specially true of rhyolite which covers so large areas in Nevada, but is wanting in this collection. It seems probable that many rhyolitic eruptions may have occurred in Salvador which will be found upon further search.

The resemblance between the volcanic products of the two regions is strikingly brought out by a comparative study of the basalts; in many instances the basalts found in Salvador exhibit an identical structure with those described from the Great Basin.*

The transition from olivine-bearing basalts to hypersthene-bearing andesites is quite the same, and moreover holds equally true for the volcanoes of Oregon, California and Washington Territory.†

Again, the relations shown to exist between the orthorhombic and monoclinic forms of pyroxene in Nevada holds true in the minutest details for the rocks of Salvador. The former yields more readily to the forces of decomposition than the latter, so that many thin sections show fresh augite and partially altered hypersthene, and others unaltered augite with wholly decomposed hypersthene. In no case had the augite been attacked while hypersthene remained unaltered.

The following list of localities includes those from which the better characterized rocks have been collected:

Basalt, from volcano of San Miguel; volcano of Izalco; Carancasuna; Quebrada de San Bartolo; San Ysidro Road; Cerro La Tabla; La Joya, Valle de Zapote.

Pyroxene-andesite, Cerro de Cunchique; Sumpul River, near Llano Malo; Sumpul River, between Oja del Sal and Las Flores; Duron's Mine; Bosque Mine.

Hornblende-pyroxene-andesite, volcano of Ilopango; bank near San Jacinto; San Sebastian Quarry; Cañon of the Tamulasco, below Las Minas.

Hornblende-mica-andesite, quarry, Cerro la Tabla.

Dacite, Cerrito de Avila; Llano de la Haçienda, one mile S.E. of San Ysidro; San Sebastian, columnar rock; Santa Rosa road, three or four miles east of Jocoro; Western Bluff of Cerro La Tabla.

ART. V.—*The Genus Strephochetus:—Distribution and Species*; by HENRY M. SEELY.

1. *Distribution.*—In communicating to this Journal, November, 1885, the existence of the fossil sponge, *Strephochetus ocellatus*, the writer named the towns Addison and Bridport in Vermont and Crown Point in New York as localities where it had been found. Further observation shows the existence of

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* F. Zirkel, Microscopical Petrography, Washington, 1876. Hague and Iddings, this Journal, vol. xxvii, June, 1884.

† Hague and Iddings, this Journal, vol. xxvi, Sept., 1883. J. S. Diller, this Journal, vol. xxviii, Oct., 1884.

the fossil over a wide area, while as a constituent of bowlders it has a still wider distribution.

On the New York side of the lake, *S. ocellatus* has been found at Plattsburgh and Chazy. In Vermont it has been observed at Isle La Motte, while the finest displays have been found in the town of Ferrisburgh, at various points, particularly at Ball's Bay just north and at Fields Bay just south of Fort Cassin. At this latter locality surfaces of rock exposing several square feet are crowded with this sponge to the exclusion of every other fossil. Specimens have been gathered at points sixty miles apart, and wherever the middle Chazy occurs, either on the western or eastern side of Lake Champlain, there one may look for *S. ocellatus.* More careful observations are necessary to determine accurately the vertical range of the fossil; probably, however, fifty feet would be a moderate estimate.

2. *Species.*—To the type of the genus *S. ocellatus* there are now to be added three species: *S. Brainerdi*, *S. atratus*, and *S. Richmondensis.*

S. Brainerdi, n. sp.

A free calcareous sponge having the twining canals peculiar to the genus, which structure may enlarge into furrows and further into well-defined cylindrical canals, and these canals may so increase in number and press upon each other that in sections they appear polygonal. The diameter of the large canals varies from $\frac{1}{500}$ to $\frac{1}{250}$ of an inch. The size of this species is greater than any other of the genus yet observed, being frequently over an inch in length. Its outline is usually oval in section, though in many cases the specimens are irregular or angular as though they had been crushed by pressure.

This form has as yet been observed only in some of the magnesian layers intercalated among the compact and fine-grained layers of the Chazy rocks in the magnificent display of these at the village of Chazy, N. Y. The specific name is given in honor of Professor Ezra Brainerd, whose careful observations and accurate measurements have added much to our knowledge of the series.

S. atratus, n. sp.

A free calcareous sponge, smallest of the genus yet recognized, having the external appearance of *S. ocellatus*, with the internal structure of *S. Brainerdi*, the small canals obscure, the larger ones distinct.

This form was obtained from the Black River limestone at McBride's Bay, S. Hero, Vt., and in the Black River limestone at the quarry of west lime kiln, Chazy, N. Y. This little fossil appears coated with black and from its covering takes its specific name.

S. Richmondensis S. A. Miller.

A free globular or sub-globular calcareous sponge, varying in size from two-eighths to seven-eighths of an inch in section, consisting of numerous irregularly concentric laminæ, separated by interlaminar spaces, filled in most cases with exceedingly small twining canals, or rarely with minute vertical tubes. These laminæ are more dense than the intervening spaces and in those examples in which the tubular structure chiefly prevails they seem the basis from which the tubes radiate. These tubes are arrested by a laminar covering and this becomes the floor for a new set of tubes. This structure of laminæ and tubes may be many times repeated.

The twining canals have the ordinary diameter of the strephochetal structure, about $\frac{1}{2000}$ of an inch, the radiating tubes vary from $\frac{1}{1000}$ to $\frac{1}{400}$ of an inch; $\frac{1}{500}$ of an inch however is the usual diameter. The irregularly concentric laminæ in cut and weathered specimens give the form the appearance of a Stromatocerium.

This fossil occurs in the upper Hudson River rocks at Richmond, Ind., Madison, Ind., and at Turners, Ky.

The description of the form, *S. Brainerdi*, is hardly complete without further reference to its remarkable structure. While externally it has the stromatoporoid appearance of the other members of the genus, its internal structure may in part vary from the typical form, by the presence of furrows and larger canals, both cylindrical and compressed. One might readily suspect on making a transverse section of some parts of the specimen, that he had in hand a coral, or possibly a coral enveloped by a sponge. But after cutting and carefully examining many sections, and especially as he saw the strephochetal portion at points giving way to furrows, and the gradual introduction of cylindrical canals of large size, and then these, pressing upon each other where the interstitial material became less, until a section was angular, he would reach the conclusion that all these various structures belong really to the same fossil.

S. atratus so nearly resembles *S. ocellatus* externally, that it may be easily mistaken for this latter fossil. Its minute structure however differs from it, and is so obscure, that it was a question whether it could be placed here. Still its general character so nearly resembles the type species, and its structure so closely repeats that of some specimens of *S. Brainerdi*, that it is safe to place it here.

In the paper referred to at the beginning of this article, mention was made of the microscopic character of *Stromatoce-*

rium Richmondense Miller. This form was originally referred to *Stromatocerium* with hesitation, the choice seeming to lie between that and *Stromatopora.* After making many sections it becomes evident that it most nearly approaches the genus *Strephochetus.* Mr. Miller has authorized the specific description above, and it is to be known as *Strephochetus Richmondensis.*

This species has several peculiarities of structure. Not unfrequently it occurs as an incrusting body, having for its core a bit of coral, or a fragment of the shell of a brachiopod. It sometimes resembles the structure of *S. Brainerdi* in the great enlargement of its canals. In this species, however, the tubes present great uniformity of direction though not of size. They run along nearly parallel with each other for a little distance, and then are cut short by a laminar covering which may be the basis for a similar set of slightly radiating tubes. This may be repeated as described in the specific characterization of the fossil, ten or fifteen times.

Sections cut in either direction, horizontal or perpendicular, suggest the genus *Solenopora*, while those of *S. Brainerdi*, in like manner that of *Chætetes.* The discovery of septa or tabulæ, in either of these tubular forms, would lead one at once to place it among the millepore corals. The character of these forms deepens the impression that the line between corals and sponges becomes in some places very narrow and indistinct.

The horizon of these different species is as follows: *S. ocellatus*, near the middle of the Chazy; *S. Brainerdi*, in the upper Dove, higher in the Chazy; *S. atratus*, in the Black River; *S. Richmondensis*, in the Hudson River.

The appearance of the members of the genus may be represented by the smaller fruits, currants, gooseberries and cherries, distributed through a paste of oolitic, fragmental or subcrystalline material. These in most cases have apparently been subjected to pressure and left in a crushed or torn condition. In weathered specimens they show a concentric structure, more or less regular, which is helpful in distinguishing the genus.

There are intimations that the genus exists in rocks higher than those mentioned, and it is quite probable that forms which have hitherto been regarded as concretionary or as pebbles, will on examination be found to belong here. The structure, which for lack of better term, we have called *Strephochetal* will be decisive on this point.

It would be highly satisfactory if it should be found, as is quite probable, that the strephochetal structure always indicates the presence of a sponge. In that case we might by it, hope to settle the question of relationship, now uncertain, of several important genera.

Middlebury College.

ART. VI.—*Preliminary Report on the Geology of the Cobscook Bay District, Maine;* by N. S. SHALER.

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PRELIMINARY NOTE.

THE following report gives a portion of the general results of two months exploring work on the shore line of the waters of Cobscook Bay during the summer of 1884. Some previous studies in this district had shown me that it afforded a very interesting field for enquiry and that it would probably furnish data of importance to the general theory of the New England coast geology. I believe the facts set forth in the following pages will justify this opinion, and moreover will show that this field contains a more interesting assemblage of phenomena than can be found on any other part of the eastern seaboard of the United States.

The United States Coast Survey has not yet mapped this district; there is indeed no chart in existence which shows with any approach to accuracy the shore line of these waters. The sketch map accompanying this report was compiled in the main from the British admiralty chart, with some additions from observations made during my summer work. This admiralty map is extremely imperfect, many minor bays, which have no value to the navigator are entirely omitted. At least ten miles of the shore line being unrepresented on that chart.

Owing to this lack of a satisfactory basis on which to record the geology of the district it has been necessary to make this report in a preliminary form. Within two years the Coast Survey topographical parties will have entered on this field and in a few years thereafter it is probable that the shore line will be so far delineated that the geological facts described generally in the following pages though left unindicated on the map, can be properly set forth.

Although, as I have recently learned, some of the fossils at Shackford head have found their way into cabinets and the fossils near Dennyville have been collected by Dr. John Shehan, a student of the geology of that neighborhood, I am not aware that there has been anything published concerning them. The collections which I made, though affording about one hundred species of fossils in a fair state of preservation, can be greatly increased by further research. It has therefore not seemed advisable to undertake a careful determination of the specimens in hand. The species have been identified only so far as was necessary to secure an approximate determination of the age of the more important fossiliferous sections.

The portion of the report which concerns the glacial and surface geology and also that describing the metalliferous veins of this district is omitted in this memoir and will be published elsewhere.

Topography of the Cobscook District.

The topography of any district is the key to its geological structure. This is especially the case with an ocean shore, for there the action of the waves and tides removes the detrital materials which often obscure the bed rocks of inland districts. A reference to a general map of the eastern coast line of the United States will show that this shore from New York northward has the general topographical form proper to the fjord zone or glaciated shore line of high latitudes.

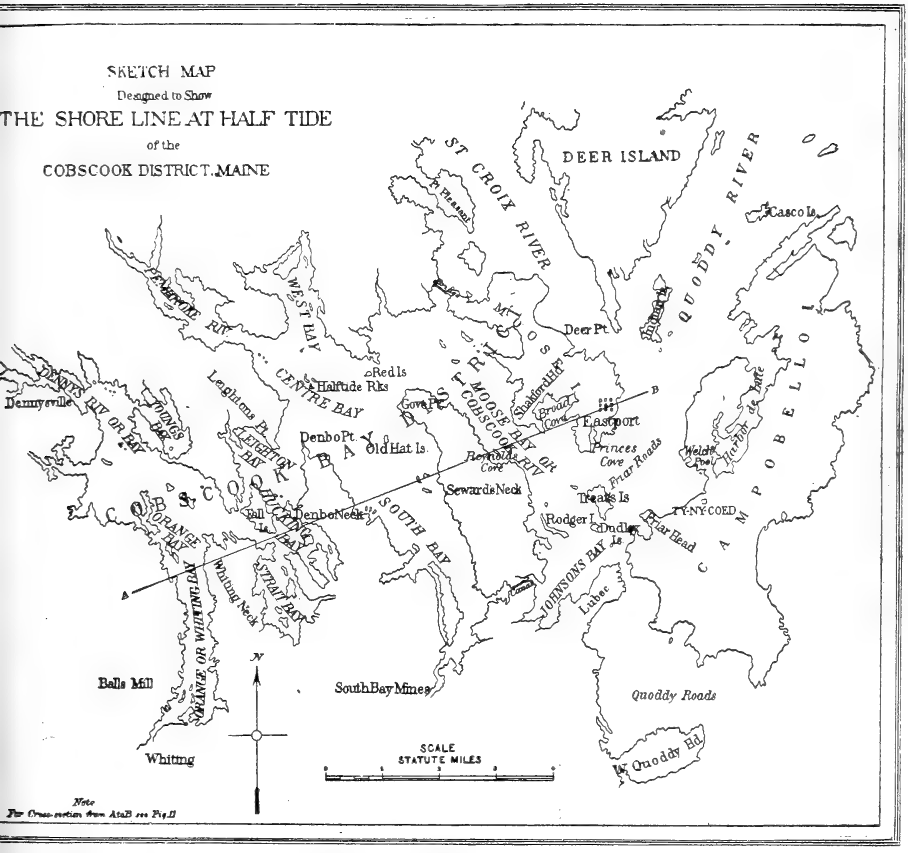
The shore is intersected by deep inlets which extend far into the land. Although these inlets have been to a considerable extent effaced by the formation of salt marshes and other deposits they are still a very conspicuous feature of this district, separating it widely from other coast lines where glaciation has not worked in moulding the land. As will appear from the evidence hereafter to be advanced in this report, the fjord structure, at least along this shore, is the result of the glacial wearing, acting upon a surface of rock of varied hardness.

Within this glacial or fjord zone of the Eastern United States we may notice several distinct varieties in the shape and character of these inlets. Along the shore north of Long Island Sound and as far east as Cape Cod the inlets are relatively far apart; their mouths are separated from each other by considerable lengths of tolerably straight shore line. Along this southern shore of New England the axes of the inlets lie nearly in the north and south line. The inlets themselves have few islands in their basins, and are in most cases relatively narrow.

From Cape Cod to Cape Elizabeth, the inlets or fjords are fewer in number and have a general east and west trend; islands are rare and, when existing, are usually composed of drift materials. The relative rarity of inlets on this part of the coast is doubtless to be attributed to the general north and south trend of this part of the shore; its trend being approximately parallel to the direction in which the glacial ice moved.

East of Cape Elizabeth the shore trends in a direction nearly at right angles to the course in which glacier flowed. Here the fjord structure is seen in its fullest development: all of the shore line is in fact made up of these inlets. The extent of the indentation may be the better appreciated by the fact that while the direct line from Cape Elizabeth to Eastport is only about two hundred miles in length, the length of the shore line, between those points, at high tide, including the coast line of the adjacent islands, probably exceeds three thousand miles.

Along this coast region of Maine we find a considerable variety in the type of fjord structure. About Portland, within the district of Casco Bay, there are no deep inlets but a profusion of small islands. From that bay to the Penobscot the strip-like fjord type of shore, narrow bays with equally narrow promontories, is the prevailing feature. At Mt. Desert the massive crystalline rocks of that region cause the coast to change its character; the bays or inlets become wider and there is an extensive fringe of islands south of the main shore.



The normal type of fjords is again found on the shore from Mt. Desert to Quoddy Head; this section differing in no important topographical respect from that between Portland and the Penobscot.

Cobscook Bay, which is a branch of Passamaquoddy Bay lying north of Quoddy Head, differs from all the other fjord systems of the United States coast in certain important features. As will be seen from the sketch map the system of fjords known by the general name of Cobscook Bay have a curiously embayed nature; all the other similarly extensive fjords of this coast communicate directly with the sea by their southern extremities, but in Cobscook Bay there are many inlets of considerable length which discharge their waters through east and west channels into each other and into the waters of Passamaquoddy Bay. It will be seen that this system of bays has three main divisions to which I have given the provisional names of Moose Bay, Center Bay and Orange Bay. This innovation in the way of names is made necessary by the fact that there are no accepted designations for these divisions though they have great topographical importance.

The general trend of these bays differs considerably from that of the other inlets of the coast. The Cobscook bays have a general northwest and southeast axis, while the other bays of this region are usually inclined a little to the east of north and west of south. In fact the Cobscook system of bays is the only system of inlets on this coast where the major axes of the basins so closely coincide with the direction of the glacial movement.

The system of bays has the further peculiarity that their borders are remarkably intersected by smaller indentations; the whole forming one of the most complicated shore lines in the world.

These peculiarities of outline indicate local differences in the bed rocks on which the glacial sheet has acted. They are sufficiently accented to make it clear to anyone who has had a little training in the interpretation of topography, that this district is occupied by rocks having a different character from those that form the other portions of the New England coast. It was indeed these peculiarities of outline that led me to begin my detailed study of the New England coast at this point. It seemed clear that there must be some important geological causes for the abnormal geography. As will be seen in the sequel this opinion has been amply justified by the results obtained.

Geology of the bed rocks of the Cobscook district.

The geology of the bed rocks of this district presents certain remarkable peculiarities. Those rocks consist of a very thick series of stratified deposits of Paleozoic and perhaps Azoic age intermingled with numerous sheets of igneous rocks which are partly intruded and partly interbedded deposits, the latter in the main apparently composed of true lavas but at certain points evidently composed of fragmental volcanic rock in the form of ash beds and breccias. In their composition, in their attitude and in their fossil contents they present many eminent peculiarities.

In the absence of any sufficient topographical survey of the district it has not been found possible to prepare a geological map which will represent even the more important features of this structure.

The following account is intended only to present the more general facts which were determinable by a preliminary inspection of the ground.

The first point that strikes the observer is that the exposures of rocks of Silurian and Devonian age which are shown in the Cobscook district, i. e. the region lying to the east of Moose Island, have nearly uniformly eastern dips. The following table of these dips will show that in localities fairly representing about one hundred miles of shore line in the Cobscook series of bays, there is very little departure from this uniform direction. It is also evident that the amount of this dip is not great and is very regular; it rarely rises above 60° and rarely falls below 20° of inclination. The few instances in which the dip of the rocks departs decidedly from the general easterly direction may be explained by local accident and do not indicate any general change in the direction of the dip. It should be said that the dips given in the table represent about the average of over two hundred observations from which the selection was made.

Selected list of dips observed in Cobscook Bay.

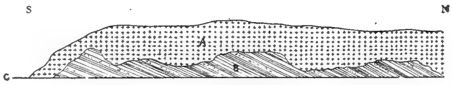
Locality.	Strike.	Dip.
McMaster's Island	N. 45° E.	S.E. 10–60°
Eastport Island, W. side	N. 45 W.	N.E. 60.
“ “ “ “	N. 60 E.	N.W. 20.
Reynolds Cove	N.	E. 20–30.
Pembroke River	N. 10 W.	N.E. 30.
Pembroke Neck, W. side	N.	E. 20–30.
“ “ E. “	N. 125 E.	S. 17.
“ “ “ “	N. 110 E.	S.E. 10.
Dudley Island	N.	E. 50–60.
Pembroke River	N. 45 W.	N.E. 55.
“ “	N. 45	N.E. 45.
“ “	N. 130 E.	S.E. 30.
South of Seward's neck canal	N.E. to N.W.	E. 10–30.
South Bay	N. 50 E.	E. 30–40.
“ “	N. 45 W.	E. 15–25.
Straight Bay	N. 40 W.	E. 35.
“ “	N. 40 W.	E. 35.

Locality.	Strike.	Dip.
Near Dennysville	N.W.	E. 15–30°.
Near Denbo Point	N. 10 W.	E. 42.
“ “ “	N.	E. 45.
“ Bay	N. 15 W.	E. 10–30.
“ “	N.W.	E. 22.
“ “	N. 90 E.	S. 15–30.
“ “	N.	E. 35.
“ “	N.	E. 20–35.
“ “	N.	E. 32.
“ “	N.	E. 25–30.
“ “	N. 40 E.	E. 40.
Pembroke River	E. & W.	N. 20–30.
“ “	N. 45 E.	S.E. 20–40.
“ “	N.	E. 20.
Johnston's Bay	N.	E. 30–50.
Shore	N. 45 W.	E. 30–50.
Fall Island	N. 45 W.	E. 28.
Orange Bay	N.	E. 50.
“ “	N. 30 W.	E. 20.
“ “	N.	E. 30–40.

At many points the igneous rocks which seem to be interbedded among the stratified deposits may be seen in what appear to be massive strata, often a hundred feet or more in thickness, having the same general dip as the rocks between which they lie. At no points are the upper and lower contacts of these igneous masses and the stratified beds clearly enough seen, or at least well enough studied, to make it possible to determine the question whether they were injected between the beds or were contemporaneous deposits.

The igneous rocks of this district may be divided into three classes: 1st. Detrital igneous rocks, those which are composed of fragmentary materials which have fallen through the air. 2d. What seem to be true lavas, i. e. those which have flowed over the superficial rocks. 3d. Dykes which traverse, strike or penetrate between previously existing beds of sedimentary or igneous origin.

1.

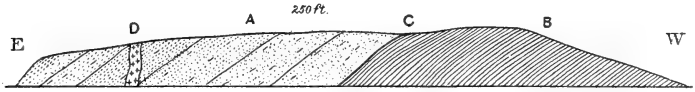


Diagramatic section of shore 1½ miles N.W. of Red Island. Length 300 ft. A, greenish diorite. B, greenish and gray flags and slates, with obscure fossils. C, high tide line.

The distinctly fragmental deposits, volcanic ashes in general character, are most abundantly exhibited in that part of Cobscook Bay which forms the channel immediately to the westward of Moose or Eastport Island. This series of ash beds covers a considerable area; in this part of the district the beds have the average dip of the rocks in the region and though their upper and lower contacts with the series of fossil-bearing beds is not well determined there can be little doubt that they are a constituent member of the Paleozoic section.

The best exhibition of these volcanic ash deposits is at McMaster's Island, a small peninsula about midway of the western side of Moose Island. This little island, of only a few acres in area, is almost altogether composed of beds of a fragmental nature. At first sight and from a little distance these beds closely resemble coarse gravel and conglomerates; but, on closer inspection they are seen to be made of fragments mostly angular, which though lying in regular beds have their major axis at all angles to the horizon; moreover, the larger bits which exceed a foot in diameter have evidently fallen with a certain violence into their places as is shown by their crushed form. All these fragments seem to be composed of volcanic or crystalline rocks, among them are many bits of pumiceous material which is rarely so vesicular as to deserve the name of pumice but distinctly related to that class of volcanic products. The evidence derived from the section at McMaster's Island and from the other exposures in the vicinity show that the set of volcanic beds exceeds five hundred feet in thickness and may be far thicker. It is likely from the width of its glacial trail in the region to the southward that this series of rocks occupies a good deal of the space of the channel known as Moose river.

2.



West side of Moose Island near N. end.

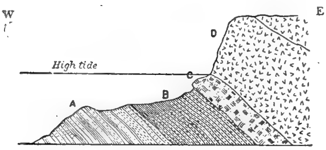
A, greenish ash beds. B, green siliceous flags. C, contact—obscure—apparently overlie. D, red felsite dyke 20 ft. wide.

The evidence goes to show that this series of McMaster's Island was formed some time before the Hamilton period. It seems clearly overlaid by the extensive series of the Shackford Head group and the equivalent beds of the Princes Cove section, while its base appears to rest upon the rocks which are probably of Silurian age.

There are some other points in the Cobscook section whose rocks of the same general structure as those of McMaster's Island are exhibited. The other exposures may or may not be of the same age as those before described. They probably represent several stages of volcanic eruption at various periods in the Silurian age.

It appears from the distribution of these contemporaneous deposits of volcanic nature that the center of eruption was to the northeastward of this district and that the intensity of its effects diminished toward the southwest. There is some reason to believe that this field of volcanic material is the extension of the ash-bed district which is known to occur near St. Johns, New Brunswick. The preliminary study of this Cobscook district has sufficed to show that in about this same horizon there are very extensive sheets of lava which were possibly surface flows, though afterwards buried beneath subsequently formed deposits. Of these the most important is a great mass of reddish felsite which occupies a wide field in the northern part of Moose Island and probably extends beneath the bays in this neighborhood. Besides this extensive sheet there is another, of the same general character, seen in the hill crowned by the old earthwork fort near the middle of Moose Island. The latter sheet of felsite is apparently interbedded in slates of Silurian age.

3.



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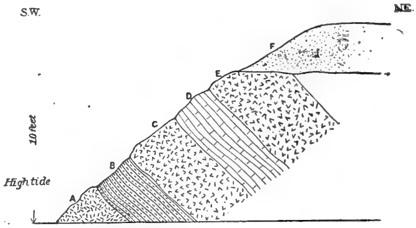
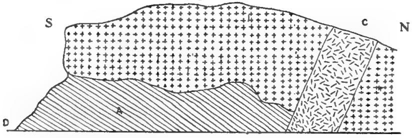


Sections on Deny's River.

Fig. 3.—A, stratified volcanic ash. B, dark colored shales. C, ash beds as before. D, fragmental trap.

Fig. 4.—A, volcanic breccia. B, shales. C, felsite. D, indurated sandstone. E, banded felsite. F, drift.

5.



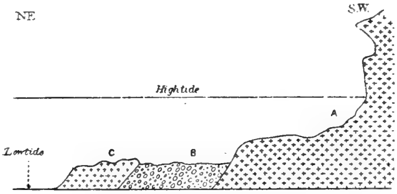
Section on shore N. of Red Island.

A, gray slabs and flags. B, greenish diorite. C, red felsite. D, high tide mark.

The felsites of this region also appear in dykes having a general north and south trend, which traverse all the other formations of this district; being perhaps the latest intrusions which have taken place. These dykes are most extensively developed in the northern part of the Cobscook district, especially in the area about McMaster's Island and in the region to the westward as far as Deny's River. The felsites are, as is well known, found in the region about Lynn in Massachusetts. The Cobscook felsites do not however exhibit the same distinct flow lines as those from the more southern localities. They have not been observed in the clearly banded or ribboned form which they often exhibit in the region near Boston.

Besides these extensive extrusions of lavas belonging to the group of felsite porphyries, there is a larger series of other dyke stones and sheet lavas which exhibit a very great variety of appearance. Some of them are of a blackish, slaggy aspect, showing a tolerably distinct bedding, which seems to arise from successive flows. The best exhibition of these slaggy lavas is at the cape known locally as Denbo Point, the extremity of which is formed by them.

6.



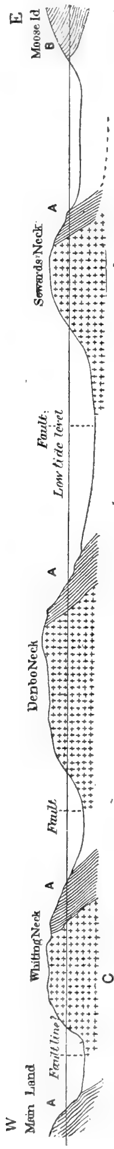
1½ miles south of Denbo Point.

A, greenish mottled trap. B, metamorphosed conglomerate. C, greenish amygdaloidal trap.

Besides the above mentioned lavas there are many other varieties of igneous rocks found in this district which are not classifiable by ordinary microscopic characters. These resemble in their general aspect the ordinary dykes of eastern New England. The classification of all these volcanic products must be left until they can be submitted to a careful lithological study.

The rocks of Silurian age are so cut up by these various intrusions that not more than one-third of the whole land area intersected by the arms of Cobscook Bay, is occupied by these strata. It seems likely that the sedimentary Paleozoic strata are extensively developed beneath the surface of the bays, the intervening ridges of land being occupied in the main by the harder volcanic rocks. That this is the case, is well shown by the fact that the stratified Paleozoic rocks are generally found as a fringe along the shores of the long, narrow capes which divide this bay into many inlets. These Paleozoic rocks are clearly less resisting to the glacial action than those of igneous origin; they are not only softer, but their thin-bedded and much-jointed condition caused them to break up under the action of the ice or waves much more readily than the compact igneous deposits.

7.

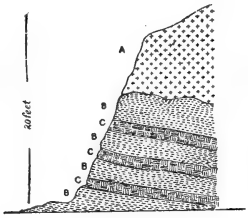


Diagramatic section from mainland to Moose Island, near Eastport, along line A, B, of sketch map. A, A, A, stratified rocks, probably all Silurian. B, Devonian. C, intruded crystalline rocks.

The greater part of these sedimentary rocks of the Cobscook series consist of very fine grained sandstones, and dark blue and blackish shales, which at certain points contain a good deal of lime, but rarely are pure limestones. At only two or three points are these beds sufficiently calcareous to be used in making commercial lime, and even at the best of these points, as in the beds exposed in Reynolds Cove, an effort to use them for lime failed, for the reason that in the greater part of the rock there was so much silex that it was apt to melt in the kiln. The siliceous element in the rock is larger than in any equally extensive section of these horizons known to me in this country, though at few points does it consist of pebbly matter; the only important exception being in certain conglomerates of a reddish color, apparently belonging to about the horizon of the Medina sandstone. These beds have so far been found only in or near the basin known as Mine Cove, an inlet near the head of great South Bay of Cobscook Bay. At many other points there are strata which contain small scattered fragments of hypogene rocks, presumably volcanic in their origin. These are particularly well shown in the extensive limestone section exposed at the head of Denbo Bay, the shallow fjord lying to the west of Leighton's Point.

The fossiliferous rocks of the Cobscook district are mostly thin-bedded, even the impure limestones, though sometimes appearing in massive form, being on the whole distinctly divided into strata of no great thickness. The general absence of detrital material derived from the land, as well as the nature of the organic contents of these rocks of the Cobscook series, favor the hypothesis that they were formed at some distance from the shore. It is generally believed that the deep sea deposits have more continuity of structure, i. e., are less divided into layers, than those found near the shore. This is probably the case with the strata formed in many parts of the sea; still we know that the Devonian black shales of the Ohio Valley termed in the Kentucky reports the Ohio shale, have a remarkable amount of stratification planes, though they were certainly formed in deep water in a position remote from the shore. We also know that any such disturbance as would be produced in the deep seas by an earthquake shock, would certainly cause a movement of the mud of the sea floor, thereby bringing about the formation of a stratification plane in the deposit. As this region was much subjected to volcanic action at the period when these sediments were depositing, we may well believe that earthquakes were common in this portion of the sea floor.

8.



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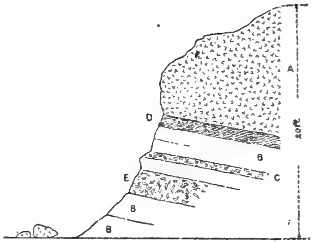


Fig. 8.—Section on Pembroke River, Cobscook Bay. A, massive trap 30 ft. thick. B, B, B, sandstones and shales. C, C, C, thin ash beds.

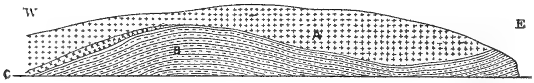
Fig. 9—Section 3 miles N.W. of Red Island. A, massive trap. B, B, red sandstone and shale. C, breccia, probably volcanic. D, irregular ash bed. E, vermiform concretions in sandstone (Scolithus tubes).

The great preponderance of siliceous and shaly beds and the remarkable absence of limestones in this district is a noteworthy feature. It is probably due in the main to the singular absence of corals and the infrequency of brachiopods and crinoids, which groups were the principal lime producers of the Paleozoic seas.

All the evidence goes to show that these rocks of the Cobscook series were in the main formed in water of moderate depth under circumstances, which, owing to some causes, were not very favorable to the development of organic life. In the latter regard this district is in striking contrast with the basin of the St. Lawrence, where during the same periods the seas contained a singularly abundant life, as is shown by the Upper Silurian deposits of the Island of Anticosti. I venture to suggest, as a possible cause of this peculiarity, the fact, that this portion of the old sea, in which the fossils of the Cobscook section lived, was on the northeastern face of the old Appalachian Island, and thus by their position were cut off from the warm current which flowed from the southwest against the ancient shores of Central New York. This same life-giving current of warm water may have found its way along the western shores of the Appalachian island to the region of the St. Lawrence.

The action of the mountain-building forces on these sedimentary deposits of Cobscook Bay has been great but extremely peculiar in its effects. Everywhere within the field of my enquiry there are evidences of much pressure, except perhaps in the southern part of Whiting or Orange Bay; that the rocks have been subjected to strong compressive action, is shown by the general distortion of the fossils. This distortion is very general; it is doubtful if in any part of the basin the rocks have entirely escaped it. The amount of the distortion varies from an elongation which does not exceed one-twelfth of the diameter to a very extreme condition, where it is as much as one-half the diameter of the distorted object, i. e. where a circle of an inch in diameter lying in the plane of the movement would be changed to an ellipse having a length of an inch and a half. Possibly one of the results of this compression is the singularly close adhesion of the fossils and the matrix. In the many thousand specimens of fossils observed, none were found fairly separated from the rock in which they were preserved. The pressure seems to have welded the walls of the fossil to the matrix in a very perfect manner.

10.

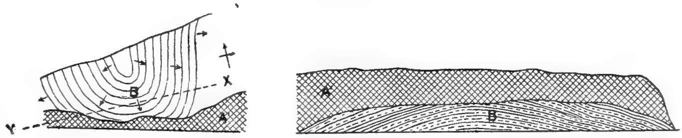


Shales and trap south end of Shakford Head.
A, overlying trap. B, dark colored shales. C, intrusive trap.

The most curious feature in the attitudes of these rocks is, that few of their dislocations take the form of folds, only three examples of folding meet the eye, in the hundred and fifty miles of cliffs inspected. (These exceptional folds are shown in figs. 10, 11 and 12.) In nearly all cases the dislocations were effected by a system of principal faults extending in a general north-northeast and south-southwest direction, cut more or less nearly at right angles by less important transverse fractures.

So far none of these fractures, except in a few unimportant cases, have been observed in the form of simple faults; they seem in nearly all cases to have been made the pathway for extrusions of igneous matter thrown out at the time when the faulting occurred. This fact seems to indicate that the source of supply of this volcanic material was very near the level of the rocks, so that no fissure of any size could form without giving exit to igneous matter. This may perhaps be explained by the fact that the rocks of this region were very near the seat of extensive and long continued volcanic action which naturally led to the formation of a very large supply of rock matter in the state to be forced into every crevice which penetrated to it.

11.

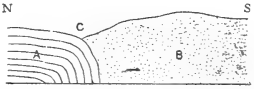


Horizontal and vertical section of small fold on shore 2½ miles N.W. of Red Island.

A, A, trappean rocks. B, B, reddish and greenish shales. X—Y, line of section 200 ft. long.

The almost invariable dip toward the east and southeast exhibited by the masses of stratified rocks in this district is a very remarkable feature in its structure, one for which I have no explanation to offer.

12.



Near N.W. end of Moose Island.

A, hard flaggy slates. B, volcanic ash. C, slickensided contact.

Extending our observations beyond the shores of Cobscook Bay, we find in the shores of Passamaquoddy Bay a considerable change of structure. The islands of Campobello and Deer Island have the general structure of anticlinals, the basin between them, known as Quoddy river, being distinctly synclinal in structure. These islands are in the main composed of a series of very compact and highly metamorphosed, non-fossiliferous schists, slates, and quartzites considerably cut by dykes, which in the main apparently belong to an older series of extrusions than those which intersect the fossiliferous rocks. These rocks, which for convenience may be termed the Campobello series, are clearly several thousand feet in thickness. They have disclosed no fossils, although a careful search has been made for them. An assistant of the present writer, Mr. G. H. Squier, a very acute observer, spent several months in a detailed study of the geology of the island of Campobello without finding the least trace of fossils in the abundantly exposed beds. The entire absence of limestones, or beds of a calcareous nature, is sufficient to show that they cannot be regarded as the metamorphosed equivalents of the Cobscook series. The general absence of lime from this Campobello series is shown by the fact that there is very little calcareous matter in the numerous veins which are found in the rocks of this series.

13.

Ideal section through Deer Island anticlinal.

A, A, Campobello series. B, B, sandstones and conglomerates: Perry series?

It will be observed from the diagramatic section showing the general geological character of Campobello and Deer Island, that they are only obscurely anticlinal in structure; being, in fact, rather complicated upheavals of intermingled stratified rocks and igneous intrusions. After they had been elevated above the sea and much eroded an extensive series of sandstones and comglomerates, which are essentially like the ordinary rocks of the Perry section were deposited upon their flanks, or possibly over the whole of the Deer Island. A further development of these axes, together with much subsequent erosion, has caused the Perry beds to appear only in the downfold between these two anticlinals.

If the Cobscook series existed on the flanks of Deer Island and Campobello, as was almost certainly the case, its beds had been eroded before the Perry series of conglomerates was laid down.

It will require much further study to unravel the succession of upheavals and subsidences which have taken place during the deposition of these rocks. There is, however, the promise of abundant reward for this enquiry, for it may throw very important light upon the history of the development of this continent.

As yet the Campobello series has not been identified in place immediately below the Cobscook series. But at various points it is seen in positions which make it a fair inference that it underlies the whole of this district. On the cape known as Quoddy Head the Campobello series is well shown in a highly metamorphosed condition. This series is traceable for three miles to the westward; indications of it were found in the region to the west of Denys River with dips which would take it beneath the Cobscook series.

In the further search along this coast for the beds of the Cobscook series, it will be well for the observer to bear in mind the fact that the Cobscook series probably lies immediately upon the more ancient beds of the Campobello series. The series of rocks exposed on Campobello is probably well developed along the coast of Maine. Rocks essentially similar in appearance to those on Campobello abound about Frenchman's Bay, and at other points to the westward. Wherever these rocks occur it seems to me there is reason to hope for some traces of the overlying Cobscook series.

One of the most difficult problems in the section is to determine the relations of the Perry series of sandstones and conglomerates to that of Cobscook Bay; at no point as yet has the former series been found in contact with the latter. But in the valley of Sipps Bay we find a series of red shales and sandstones, which has a thickness of over fifteen hundred feet, and probably belongs to the Perry series. These beds have the same general dip as those of the Cobscook series, where the latter series is shown about a mile farther to the south. It is likely that a careful search in this part of the field may reveal a contact of these two sets of beds.

On the mainland just north of Moose Island, and thence up to the town of Perry, similar sandstone and conglomerate beds are shown, with a strike which would place them above the beds of the Cobscook series of that island. But in this Perry district the section of red shales and sandstones lies apparently on the denuded edges of the granitic and syenitic rocks which form a yet lower series than those which furnish the floor of the red conglomerates and shales of Deer Island. That is to say, while the Perry series of Deer Island lies on the old slates of the Campobello series, in the more northern exhibition of the beds they are directly on the rocks of presumably Laurentian age. The Perry series of rocks appears to be much less cut up by dykes than the underlying Cobscook series; no intrusions of igneous matter were observed in the outcrops which were studied. This makes it probable that the time of most intense volcanic action had passed away before the Perry series was deposited.

Thus this district seems to contain the following more or less well indicated series of stratified rocks. At the base a series whose thickness is unknown, consisting of gneissoid syenitic and granitic rocks and some mica schists; of this series little is known: it is the prevailing series of crystalline rocks along the coast of Maine, and is probably of Laurentian age.

Above these series lies a second which for convenience we have termed the Campobello group, comprising a set of dark greenish and grayish siliceous and argillaceous rocks containing very little lime.

This Campobello series has a thickness of at least four thousand feet and may be thicker; the rocks appear to be entirely destitute of fossils though they are not so much metamorphosed as necessarily to lose by this change all trace of fossils if they had once contained them. This section may be equivalent to the slates of the Cambridge district in Massachusetts, and generally of the Cambrian slates about Boston, which they resemble in a general way, especially in the remarkable absence of lime in their composition. This Campobello series probably rests immediately on the subjacent older series of Laurentian age, and may represent the lower Cambrian section, but the phenomena of contact with the underlying beds are unknown. Above these Cambrian layers, and without observed contacts with them but with scant place for any intermediate deposits, lie the beds of the Cobscook series. This series has a thickness in all of not less than four thousand feet, and on careful study may be found to have much more than this depth. Although the contact between this series and the Campobello group is not known, the facts justify us in saying that an extensive elevation and erosion of the last named deposits took place before the deposition of the Cobscook series was begun or after they were formed, for they were not present on the Deer Island anticlinal or on the banks of the St. Croix river, where the Perry series was laid down. The presumption is that they were originally in place on these surfaces, but were worn away during the interval between the close of the Cobscook series and the formation of the Perry beds.

Last in this succession of deposits we have the coarse red sandstones, conglomerates and reddish shales of the Perry series. This deposit is certainly over two thousand feet in thickness. It differs very widely from those which occupy a lower level in this district; nearly all the other deposits seen are mainly if not entirely made up of materials such as may be laid down in a tolerably deep sea. The Perry section was clearly formed in shallow water in immediate proximity to the land.

If the lower part of the section at Perry should turn out to be upper Devonian or Sub-carboniferous, as seems not improbable, then the evidence will be to the effect that a period of erosion occurred in the interval between the close of the middle Devonian section and the formation of the Perry beds. This is especially interesting, as it would seem to show that this portion of the continent was above the sea during a part of the Devonian, or of the Sub-carboniferous period. Moreover, the character of the sediments which formed the Perry series favors this view. Those are clearly materials which were derived from neighboring lands. If we could assume with Sir A. C. Ramsay that all such red sandstones as are found in the Perry section were formed in fresh or brackish water, then this series would perhaps indicate a time when the shore line was at or near its present position. This view is rendered quite probable by the fact that the Perry beds have yielded a certain number of land plants, and so far has furnished no trace of fossils which could have been formed in marine deposits. I do not propose at present to consider the age of the Perry series, as the problem is one of peculiar difficulty and requires a much more extended study than I have been able to give to it.

We shall see in the subjoined account of the fossils from several horizons of the Cobscook series that what appear to be the uppermost beds of that series contain an assemblage of forms which belong in the Devonian section. These fossils are in a very thick section of blackish slates resembling in certain features the Devonian black shales of the Mississippi valley and the basin of the great lakes. These beds, like their presumed western equivalents, probably were deposited in the waters of a deep sea at a considerable distance from the main land, yet in a time that cannot be. very far separated from these Moose Island shales, as I have termed the black shales of this series. The Perry sandstones were deposited in conditions that show that they were made on the mainland or in an estuary basin. Thus the elevation which followed the deep subsidence occurring in the time of the Moose Island black shale, appears to have brought this part of the continent above the sea level, while in the Ohio basin it only served to shallow the water and bring the shore nearer than it was before.*

Although these conclusions as to the divisions of the rocks in the regions near Eastport must be subject to review after a more thorough knowledge of this district is attained, they are sufficient to show that the oscillation of levels of this district and the data attainable from the composition of the sediment, will afford some important clues to the geological history of the continent. It should be said that these divisions of the rocks in and about the Cobscook district are presented with much hesitancy; although it may be found in the end to be extremely imperfect, it will at least serve as a basis on which to build a more critical study of the rocks of this region.

Fossiliferous Horizons of the Cobscook series.

We turn now to the problems connected with the stratigraphic equivalency of the various divisions of the Cobscook series. It has also been noticed that the very great amount of igneous injections and the extensive erosion to which this district has been subjected has made it very difficult to determine the stratigraphical relations of the fragmentary sections which remain. This problem is still further complicated by the difficulty which is found in using the fossils contained in the rocks

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* It may be incidentally suggested that the conglomerates and sandstones of the Perry series should be compared with the deposits of the Catskill period of the Hudson district.

as data for the identification of their age. Of the hundred or so species of fossils which have already been approximately determined, the greater part are either distinctly unlike those obtained elsewhere, or belong to forms which have a wide vertical range in the rocks of other districts. A number of the most interesting forms are so far novel that they offer no evidence of value as to the age of the beds in which they occur. Moreover, judging from the other known deposits of middle Paleozoic age on the Atlantic slope, those of Newfoundland, New Brunswick, and Nova Scotia, the typical divisions of the New York section or of the Mississippi valley, do not retain their limits on the eastern shore of the continent. The Silurian deposit of Anticosti cannot be precisely paralleled with those of the interior basin and much the same lack of definite relation to the western section is found in all the horizons which are represented on the Atlantic coast basins. This difficulty is one which might fairly be expected. The faunal divisions in contemporaneous strata of the Paleozoic rock though less clearly marked were hardly less numerous than those of the present day, i. e., the faunal areas whether determined by the difference between deep sea and shallow water, or by the difference between the sides of a barrier such as separated the Paleozoic deposits of the continental basin from the Atlantic coast were as numerous as those in the existing seas.

Although these divisions were nearly as distinct in the Paleozoic era as found at the present time, there was, it is true, no such delimitation of zoological or botanical provinces as at present; no such difference as those which now separate the Australian from the American province existed in the Paleozoic time, but the lesser differences of faunal divisions, though not so much accented, were something like as numerous as at present. It is therefore by no means surprising that we find difficulty in determining the relations between the deposits of the Cobscook series and those of the typical western series of the continent.

The Cobscook series presents us with the several sets of beds which in their physical characters and their organic contents seem to indicate separate horizons. By far the richest horizon yet found in this series is that which is shown on the west side of Orange or Whiting Bay about half a mile south of Ball's Mill. At this point the fossiliferous strata are seen with a thickness of about twenty feet. On the west they are cut off by an extensive series of dykes and in the east they dip below the level of the bay.

These beds are only exposed below high tide mark which fact made collecting in the few hours on two days when the locality was visited, very difficult. The rock is a very dense, much jointed, siliceous limestone; the fossils are less distorted than any others yet found in this basin. They appear on the fracture faces of the rock with great clearness of outline and are extremely abundant. From about five hundred pounds of material selected from the upper ten feet of this section, careful dissection with hammer and chisel developed the fifty or more species from which the position of the group has been preliminarily determined. It is probable from the results obtained that at least one hundred species may be obtained from this point. The next most important locality which is as a horizon to be separated from the Orange Bay section is that exposed in Denbo or Leighton's Bay, about two miles to the northwest of Denbo Point.

This locality exhibits at least two hundred feet of shales and impure limestones. These beds are barren of fossils in the lower parts, but in the upper hundred feet contain about thirty species of fairly well preserved fossils. At this point the beds are much distorted, the fossils having an average elongation of one-fourth their original measurements. The strata are much softer and thinner bedded than those of the preceding section, to which is perhaps due their greater distortion from pressure. None of the species from this and the preceding locality are precisely identical, though there are certain species common to the two localities which are closely allied to each other.

The third locality which gives hopes that it may prove the basis for a separate horizon is that shown about one mile northeast of Dennysville. As yet this locality has been imperfectly studied: the beds appear some distance below the water line in very solid ledges which will require a considerable use of powder before they will freely yield their fossil contents. The small amount of material gathered seems to indicate that the deposits are closely related to those of the Orange Bay section, but probably represent a separate and inferior horizon.

On the eastern shore of Seward's Neck near the north end of Roger Island, and again at Reynolds' Cove, there are considerable exposures of compact, thick-bedded limestone which distinctly differ in their general aspect from the other horizons of the series; there are only a few species of fossils in this section and these are very imperfectly preserved.

On the Denbo shore, i. e., the western shore of Great South Bay at about one and one-half miles south of Denbo Point, there is a locality exhibiting very massive beds of limestone having a rich brachiopodal fauna. The contained fossils have been very much modified by pressure, being very greatly extended in the northeast and southwest axes. The outcrop of these strata consist of singularly smooth "roches moutonées," from which only small quantities of the rock could be detached. The fossils promise to afford a series very nearly connected with those in Leighton's Bay and probably of the same age but representing a different association of fossils. On the west shore of Straight Bay there is another set of rocks affording a section over one hundred feet in thickness containing a limited but peculiar fauna.

The last of these important sections is that exhibited on Moose Island, on which Eastport stands. This consists in a great thickness of shales of a generally dark carbonaceous look, reminding the observer, as has already been remarked, of the Devonian black shale of the Ohio valley and western New York.

The Moose Island series is rather thicker bedded than the ordinary Devonian shale; its upper part is composed of dark, siliceous flags, with occasional interbeddings of what will probably prove to be volcanic ash deposits. The section as a whole is decidedly like the Devonian black shale. The series, as far as exhibited, has a thickness of about one thousand to fifteen hundred feet, but neither its superior or inferior limits are seen.

The Orange Bay section, being that which is richest in its fossil contents may, in the determination of these various horizons advantageously be used as a datum level. If its stratigraphic position can be approximately determined, the other sections can then be grouped about it. This seems a more feasible way of approaching the problem than by trying to make separate identifications for each section in the basin.

The following list of fossils from this last named horizon, with the comments given therewith, will serve to show the data which are now in hand for determining the geological age of the beds.

List of Species.

Mollusca.

Orthoceras perstriatum.
" tenui-annulatum.
Holopea antiqua, var.
Platystoma depressum.
Platyceras lamellosum. ?
" platystomum, var.
Loxonema allied to L. Fitchii.
Anatina sinuata ?
Avicula allied to A. manticula.
" " A. securiformis.
" " A. communis.
Megambonia allied to M. lata.
" " M. ovata.
Spirifer modestus ?
" perlammelosus.

Spirifer cyclopterus ?
" octocostatus.
Rhynchonella mutabilis.
" abrupta.
" vellicata, var.
" formosa.
Rhychonella æquivalvis, var.
Rennselæria allied to R. ovalis (doubtful).
Leptocœlia allied to L. fimbriata.
" " L. concava.
Atrypa reticularis (extremely abundant.)
Orthis pedunculosa, var.
" planoconvexa, var.
Strophodonta planulata, var.
" Beckii, var.
Trematospira allied to T. Deweyi.

Articulata.

Dalmanites closely allied to D. micrurus.
Tentaculites irregularis, var.

In this and the following lists of species no revision of the generic and specific names has been attempted.

The thirty-three species of fossils which are named in the preceding list, have been in the main determined from casts of the exterior or interior, of the shells or other hard parts; this being the form in which the remains are commonly preserved in the beds of this locality. The species from the equivalent New York strata have generally been described and figured from specimens which show the substance of the hard parts. Any one who has undertaken identifications under these circumstances, must have remarked the difficulties involved in such comparisons. Despite these hindrances to complete determination, the identification may perhaps be taken as sufficiently accurate to serve the needs of the problem in hand.

There can be little doubt that these species prove the beds from which they came to be, in a general way, the equivalent to the Lower Helderberg group of New York, but it does not seem possible, at least at present, to refer the deposit to any particular division of that series of beds. It should also be noticed that there remain at least twenty species of fossils from this locality, which are as yet unidentified many of which may hereafter be found to belong to other geological horizons; moreover nothing like a complete collection of the fossils contained in the deposit has yet been secured.

Although the species given in the above list are in most cases closely related to the forms to which they have been referred, it must not, for the reason before given, be assumed that complete specific identities have been proved; that degree of accuracy in the determination cannot be secured until much more extensive comparisons are made.

It should be noticed that there are many genera of fossils which are commonly represented in the deposits of Lower Helderberg age, which have not as yet been found in this series of rocks. So far the abundant collections have shown no Lingulas, no distinct Meristas, no Nucleospiras, no Trematospiras, no Leptænas of the *L. depressa* type and very few species of the genus Orthis. There is scarcely a trace of corals or crinoids; no Bryozoa have been found.

The next locality of importance is that near Dent's Point, at the head of what is locally known as Leighton's Cove. The physical character of the rocks differs considerably from that of the Orange Bay deposits, before described. The Leighton's Cove series consists in the main of shales generally thin-bedded and containing but little lime. About two hundred feet in thickness of beds is exposed, but of this only the upper half is fossiliferous. The fossils are well preserved, but have been subjected to a considerable distortion from pressure; the elongation being in a general northeast and southwest direction. Thirty species have been found in these beds, of which the following have been approximately determined.

List of Species.

Dalmanites limulurus. Clinton.
Beyrichia symmetrica. Niagara.
Orthoceras imbricatum.
Orthis allied to O. elegantula } as usual these two forms blend
    "   O. hybrida } together. Niagara.
Atrypa cuneata, var. Niagara.
Chonetes allied to C. cornuta, but much larger and with finer ridges. Clinton.
Orbicula squamiformis, var. Niagara.
Lingula oblata. Clinton.
Avicula allied to A. textilis. Lower Helderberg.
  " emacerata. Niagara.
  " rhomboidea. Clinton.
Modiolopsis sublatus. Niagara.
    " ovatus, var. Clinton.
Orthonota curta, var. "
Cyclonema ventricosa. "
Murchisonia subulata. "

The greater part of these species are represented by abundant but poorly preserved specimens. Although the identifications are not perfectly satisfactory, they serve to show the relation of these beds to the horizons of the Clinton and

Niagara in New York. The dozen or more, less well determined forms, the names of which are not given in this list, probably belong in the same series of strata.

As the collections made at this locality came from about one hundred feet in thickness of beds and contain several thousand specimens, they may fairly be taken to represent the general nature of the life of the Clinton and Niagara epochs in the sea of this region. It is interesting to note the fact that several very important and elsewhere abundant genera and families of animals are not represented here. Not a trace of a coral and no bryozoan has been found in the collection. Crinoids are extremely rare and are represented by a few small fragments of stems. Among the Brachiopoda the Strophomenas are represented by only one obscure species, and the characteristic Strophodontas do not appear; the genus Orthis is very scantily represented. The most abundant group in number of species is that of the Lamellibranchiata.

So far not one of the species in this locality has proved to be clearly identical with those collected at the previously described locality in Orange Bay, but it is not impossible that among the undetermined forms some species common to both may be found.

The next set of beds in order of importance, which permit of approximate identification, are those which are exposed at a point about one mile northeast of Dennysville. These beds are scantily exposed in the belt below the high tide level, where they appear in the form of low glacially worn ridges. The specimens collected from this locality probably represent in a very inadequate way the fauna found in the rocks.

The total number of species collected is about twenty, of which the following are approximately identified.

LIST OF SPECIES.

Pleurotomaria percarinata, var. Trenton.
Atrypa nitida, var. Niagara.
" aprinis, var. Niagara.
Spirifer crispus, } not distinctly separable. Niagara.
" bilobus. }
Syringopora multicaulus? Niagara.
Heliolites spinipora. Niagara.

All the unidentified forms from the preceding locality seem to be related to Niagara species. Thus, as far as this limited evidence goes, these beds are to be taken as belonging to the Niagara limestone, or at least having a close relation to the beds of that horizon.

By far the most important section of the paleozoic series of rocks as regards its thickness or its geological significance which is exhibited in this district is that which is found on the western side of Moose or Eastport Island. As before noted I propose to term this section the Moose Island series for the reason that the beds are most abundantly developed on that island, it being indeed doubtful if they occur elsewhere in this district. These deposits consist mainly of black and dark gray shales and slates. They are exhibited at several points along the western shore of Moose Island from north of Shackford Head to near Eastport. The total thickness of the section is not known as neither its superior nor its inferior limits are disclosed. It is evident, however, that at least one thousand or one thousand five hundred feet of beds are shown in the several exposures, or indicated as in existence between the outcrops.

The dark color and the shaly nature of these beds will remind any one familiar with the aspect of the Devonian shales of Western New York and the Ohio Valley; the deposit which has been termed the Ohio shale in the Reports of the Kentucky Survey. Although fossils abound at Shackford Head and Princess Cove, they belong to few species and are not very well preserved, having been somewhat distorted by the considerable pressure to which the beds have been subjected. The following species are fairly recognizable.

LIST OF SPECIES.

Modiomorpha, allied to M. subulata.
" sp. undetermined.
Murchisonia desiderata. ?
Beyrichia, species not determined.
Lingula, a species not determined.
Discina, two species.

The total number of species recognizable in the large collections made at this point does not exceed ten, though the individuals amount to many thousand. Though these forms taken alone afford slender ground for identification of the deposits, still they are entirely consistent with the supposition that the series is equivalent to the Ohio shale.

It is much in favor of this view that the beds occupy a position where we might fairly expect to find the Devonian series of rocks. Thus though it is not safe to affirm that this series belongs to the Ohio shale it is undoubtedly the most reasonable supposition that can be applied to the facts.

If it should in the end be found that these beds represent the great Devonian shale it will add a new interest to that remarkable deposit: so far this series of the Ohio shale has not been clearly traced in the section east of the central Appalachian axis. If these beds at Eastport belong to the Devonian shale it had an extension to the east which must carry it beneath the Atlantic Ocean. The exact determination of the age of these beds is one of the most interesting matters for future research afforded by the geology of the Cobscook region.

Besides the above mentioned localities where organic remains have been found there are many others, a score or more in number, scattered along the great length of shore of this region, which to my preliminary study yielded too few and altogether too imperfect fossils to make it profitable to undertake the determination of their age. It seems possible that among these beds there may be found traces of the fauna of the lower Silurian, especially of the Trenton and Hudson River groups. If these faunæ are represented at all, it is clear that they are shown in a very imperfect manner, still the search has as yet been so inadequate that much may yet reward the careful explorer. There is reason to believe that these fossil-bearing Cobscook rocks extend much farther to the west than they have yet been followed. It is also probable that they may be found considerably to the north of the points where my explorations were carried.

From the foregoing summary of my observations in this region it will be seen that it affords a large field for profitable study. It seems likely that at least three hundred species of fossils may be gathered from the localities exposed along the cliffs of the Cobscook fjord system, many of them are undescribed forms, and in all cases they depart in an interesting manner from the types found elsewhere.

The problems now are to compare these species with those from the classical localities of New York and elsewhere, so as to determine how far the horizons accepted in those regions may be recognized in the Cobscook district. This task cannot well be undertaken until the topographic representation of this district is on a satisfactory basis. Such is the complexity of the topography as well as of the geological accidents that nothing in the way of final work can be done until a good map is secured. As the parties of the United States Coast Survey expect to be working in this region in 1887 we may hope to have the basis for a good map before 1890, it may be well to postpone the delineation of the geology until that time. In the meanwhile the more important parts of the geological work, all that relates to the assimilation of the deposits to those of other districts, can be carried on.

It seems to me that it will be well to extend the search for the beds of the Cobscook series to the shore line both to the east and west of the region treated of in this preliminary report. It is not likely that they have been preserved on this portion of the shore alone. Their general character shows that with the exception of the Perry beds they were deep sea deposits and therefore presumably covered all this part of the coast. They may fairly be expected to appear both in the southern part of New Brunswick and along the Maine shore to the westward.

It is particularly important that they should be sought for elsewhere for the reason that in the Cobscook series it is evident that not one-twentieth part of the total fossiliferous section is revealed. The greater portion is completely covered by the extruded rocks, or is buried beneath the glacial drift, or is hidden by the waters of the bay. If the beds are found elsewhere there is reason to hope that these hidden portions of the section may there be exposed to view. In this way we may hope to complete the stratigraphic as well as the paleontological series of the district.

Nearly every exposure of fossiliferous strata which occurs in this region manifestly owes its preservation from glacial and other wear, which would have eroded the beds to below the sea level or removed them altogether, to the protection afforded by the dense and erosion-resisting covering of lava which lies upon it, or has only recently been worn away. This points to the conclusion that in searching for these deposits in the neighboring parts of the coast it will be well to examine every point where stratified rocks appear beneath the cliffs of igneous rock; such being the position in which these relatively soft beds are most likely to have survived the destructive effects of glacial and marine erosion, both of which causes have acted with peculiar energy along this shore.

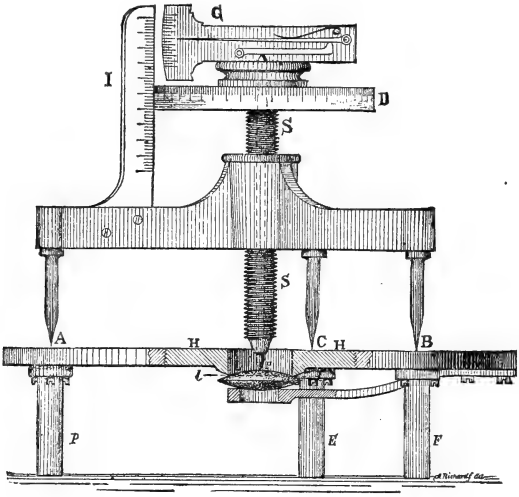
It should be borne in mind that these fossiliferous horizons have an especial interest from the light they may throw on the position of the shore line in past times. Therefore not only the organic remains which they contain but also the detrital matter of which the rocks are formed is of much importance. The occurrence of a conglomerate apparently of the Clinton or Niagara age in the section on the western shores of South Bay seems to show that the shore in this district was not far away during a portion of the time when the Cobscook series was forming. The general character of the pebbles in this bed indicates that the ancient shore was composed of the hypogene rocks, syenites, etc., which now constitute the principal materials exposed to erosion in this part of the continent. Again in the age of the Perry section we have evidence that the shore line was near its present position and that the rocks exposed to erosion were principally of Laurentian age. Thus it is evident that we may reasonably hope, from the study of this field, to find our way to conclusions of great value to American geology.

ART. VII.—*On the Well-Spherometer; an instrument that measures the radius of curvature of a lens of any linear aperture;* by ALFRED M. MAYER, Professor in the Stevens Institute of Technology, Hoboken, New Jersey.

DURING the past ten years I have used in my laboratory a spherometer that gives measures from which we can compute the radii of curvature of lenses of very small linear aperture. This instrument I exhibited, and its mode of use I explained before the National Academy of Sciences on Nov. 15th, 1882. The spherometer, as generally made, cannot measure the radii of lenses of small diameter, by reason of the large spread of the feet of the tripod that support the micrometer screw. On some spherometers these feet are made to slide toward the screw till they are equidistant from it, and so near to it, that they can stand on the surface of the small lens whose radius is to be measured. The objections to this arrangement are: (1) that when the feet are thus brought near the screw the instrument is top-heavy, and it becomes difficult to determine nicely the contact of the point of the micrometer screw; (2) that it requires expensive workmanship to make these slides carry the feet so that the plane passing through their points shall remain at right angles to the axis of the screw; (3) the difficulty of adjusting these feet so that they are equidistant from the axis of the screw; (4) the difficulty of measuring what is known as "the radius of the instrument;" i. e. the distance of *the points of contact* of the feet from the point of contact of the screw. This objection (4) applies to all spherometers except the one described in this paper. The necessary curvature of the terminal points of the tripod renders the radius of the circle, including these points of contact, variable with the radius of lens; and these points of contact cannot be determined with precision except by difficult measurements on the form of the points and subsequent troublesome computations; and then both the zero reading of the screw and the radius of the instrument are changed from what they were when referred to a plane surface. It has been attempted to overcome this objection by making the points exceedingly fine; but in this condition they are soon blunted by use and deformed by the least carelessness. (5) To be able to bring the feet of the tripod sufficiently near the axis of the screw to measure lenses of very small diameter, these feet have to be made very delicate and the screw has to be terminated by a long pointed rod; thus making the feet liable to spread from the weight of the instrument pressing them upon a curved surface of small radius.

The instrument which I now describe is, I think, free from these objections and has, in my practice with it, given accurate results.

1.



The points of the tripod A, B, C, fig. 1, rest on a plane surface. A disc of steel H, H, is screwed into the plate of the instrument, this disc has a cylindrical aperture, or well, accurately formed. The surface of the mouth *l*, *l*, of this well is turned to a sharp edge by a hard tool with a sharp and properly formed cutting edge.

To measure the radius of a lens, a steel disc is selected whose aperture is smaller than the diameter of the lens, and it is screwed firmly into the plate. A piece of flat glass is now pressed by a spring against the lower opening of the steel cylinder, and the reading of the head of the screw is taken when the pressure of the point of the screw on the glass plate makes the contact-lever, G, read zero. The flat plate is now replaced by the lens, D, and the screw is approximately centered in the steel well. The screw head is turned till the contact-lever reads zero, then the spherometer is slid over the top of the lens till the contact-lever gives the highest reading, the axis of the screw then coincides with the axis of the well, and is in line with a radius of that portion of the lens contained above the plane passing through the mouth of the well. The instrument, now stationary, is adjusted till the contact-lever reads zero. The difference of this reading and the one obtained when the screw was in contact with the plane surface gives the height of the section of the lens above the plane of the bottom of the well.

The interior diameter of the cylinder is found by accurate measures with vernier-calipers, or by measures with a dividing engine furnished with a micrometer-microscope. Then the formula $R=\frac{r^2}{2h}+\frac{h}{2}$ gives the required radius. R=radius o lens; r=radius of interior of well; h=versed sine of radius of lens, or, height of section of lens above edge of bottom of cylinder.

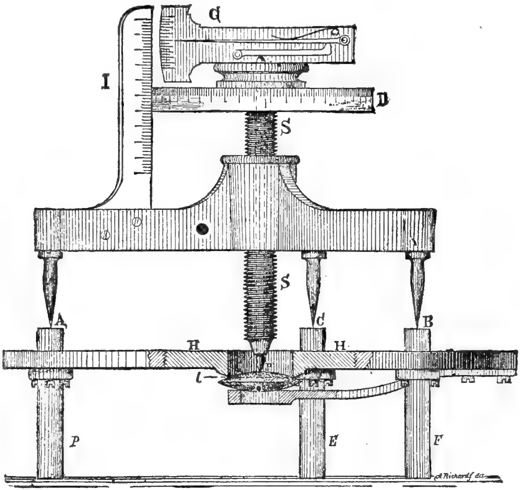
When the radius of a concave spherical surface is to be measured, the outside edge of the cylinder is used. The diameter of this cylinder can be very accurately measured. The same cylinder may do for measurements on either concave or convex surfaces if its outside and inside edges are made by a plane perpendicular to the axis of the cylinder. This form of cylinder I have generally used. Four or five of these of different diameters will be sufficient for most work. The interior diameters, I have selected are ·2, ·35, ·6, 1·00, and 1·7 inches; or, in millimeters, say, 5, 9, 15, 25, and 40·5. The thickness of the cylinders are about $\frac{1}{16}$ in. or, $1·5^{mm}$.

In the account of the measures with this instrument it has been assumed that the tripod of the spherometer rests on a plane surface and also that the plane of the bottom of the well is parallel to this surface. It is not difficult, now that Brashear has reduced to practice the elimination of the errors of an approximate plane, shown by the most delicate test which applies itself to the whole plane at once (namely, the interference bands produced by reflection from the surface of the plane required and the surface of a true plane of glass resting on it), to obtain planes whose departure from truth is less than the indication of the best spherometer. In the planes I use, one of glass, the other of steel, my spherometer, by Brünner, of Paris, does not show a departure from a true plane of $\frac{1}{125000}$ of an inch. These planes, however, when being made were not tested by the optical method. The parallelism of the plane closing the bottom of the well and the plane on which the spherometer rests is, of course, given by the spherometer itself if this be an *instrument of precision.* This it only is when furnished with the means of getting contact by the intervention of a lever, level, or the electric-contact. Every instrument of precision contains in itself the means for its adjustment and for the determination of its errors of measurement. If when the spherometer is brought to the zero reading and the screw is moved over the plane forming the bottom of the well, this adjustment remains in all positions of the screw on the plane, then the two planes are parallel. Any want of parallelism can be detected to $\frac{1}{125000}$ inch. I state this quantity so as to be within bounds; for from nine settings of the Brünner spherometer I found that the extreme

+ or − departure of single measures from the mean of the nine is only $\frac{1}{1250000}$ inch.

In one spherometer, which I have, fig. 2, the axis of the screw is made so that it coincides with the axis of the well. In this instrument two of its feet rest in conical holes; the third foot in a V cut in the direction of a line joining this foot with the axis of the well. Any want of parallelism between the planes cannot be determined in this form of apparatus. If this error exist it has to be computed and allowed for; and for this we have to know the inclination of the planes. This can be measured, in the other forms of spherometers described, by several optical methods. If the plane at the bottom of the well should be tilted 1°, which is an inclination far beyond that which would be made by any one honestly calling himself a skilled mechanic, the error in the measurement from the true height of the section of a lens of 2 in. radius and ·2 in. thickness would equal +·000027 inch. This error is however difficult to compute and is not susceptible of a simple expression in terms of the inclination of the planes and of the radii of lens and well.

2.



If x = the true height of section of lens above bottom of well;
a = measure really made, at an angle to plane of bottom of well;
θ = angle formed by the two planes of the spherometer;
r = radius of curvature of lens;

$$x = a\cos\theta + \frac{a^2}{2r}\sin^2\theta + \frac{a^4}{8r^3}\sin^4\theta + \text{etc. or,}$$

$$x = a\left(1 - \frac{\theta^2}{2} + \frac{\theta^4}{24} - \text{etc.}\right) + \frac{a^2}{2r}\left(\theta - \frac{\theta^4}{3} + \frac{\theta^6}{30}\right) + \frac{a^4}{8r^3}\left(\theta^4 - \frac{2\theta^6}{3}\right) \text{ or,}$$

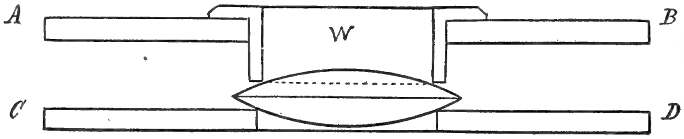
$$x = {\cdot}99984760d + {\cdot}000152284\frac{d^2}{r} + {\cdot}00000012\frac{a^4}{r^3}$$

It is better to use the spherometer of the form given in fig. 1, and to bring the planes to true parallelism; which can be accomplished by placing thin foil under the flange of H, H (not shown in the figure). This tilts the axis of the well so much from its previous position that the instrument retains its zero reading when the screw is moved over the plane at the bottom of the well.

The contact-lever on the Brünner spherometer differs from that shown in the figure. The lower end of a delicate contact-lever is bent at right angles and at the angle of this short arm of the lever is the fulcrum. At the other end of this short arm is a point at right angles to it. A delicate spring constantly presses this short arm of the lever downward. The point on the short horizontal arm of the lever is the contact-point used in making measures. This delicate lever is carried on a piece of metal which slides in a guide attached to a horizontal arm of the tripod. The ends of this piece of metal are bent at right angles, and between these are embraced the screw. The lower end of the screw rests in a conical hole in the bent arm, and a set-screw enters a conical hole in the upper end of the screw. On the longer and vertical arm of the contact-lever is a lug on which is engraved a fine line. When this line is made to coincide with a line, drawn on a standard, the screw is at zero of contact. The coincidence of the lines is obtained by means of a microscope attached to the instrument.

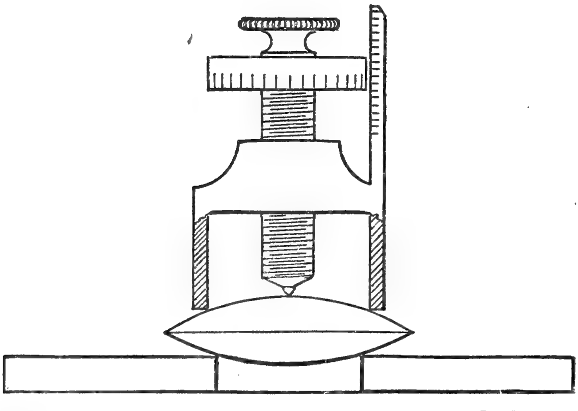
Mode of measurement with the well and the ordinary spherometer.—The ordinary spherometer is simply a tripod, supporting a nut N in which runs a screw P. The head of the screw is divided into fractions of a revolution, and the pitches of the screw are read on a vertical scale attached to one of the legs of the tripod. The zero reading of this apparatus is obtained when the four points, those of the tripod and that of the screw, are in the same plane. The most accurate way of getting this adjustment is to place the plane on the top of a resonant box and to run the screw down till it lifts slightly two of the feet of the tripod above the plane. Then, on quickly and gently tapping the plate a rattle will be caused by the instrument vibrating about the screw-point, which is its highest point of support. If the screw be run slightly upward this rattle will become just audible and then, on a very small amount of rotation of the screw, it disappears. The reading of the screw may now be taken for the zero-reading. If this reading is obtained by an upward motion of the screw then all subsequent measures referred to this one should be made by contacts obtained by the same direction of motion; otherwise, the "back-lash" of the screw will enter to vitiate the measures. I have found that contacts on a large plate can be obtained by this rattling-test to $\frac{1}{50000}$th of an inch. It must not be inferred, however, that other contacts, like those on the top of a small lens, or on a small and thin plate, can be determined with the same accuracy. The very test requires vibration and unsteadiness in the instrument; and these conditions are not those for precise work. This ordinary spherometer cannot, in my opinion, be regarded as an instrument of precision, like the lever-contact spherometer.

3.



In measuring radii of lenses with the ordinary spherometer we use a plate A, B, fig. 3, with a hole in its center. In this hole is cemented the steel well W, whose lower opening rests on another plate. This rests on the resonant box. Parallelism of the surface at the bottom of the well and that of A, B, on which stands the spherometer, is determined by the rattling test. If this parallelism of the plates does not exist, it must be obtained by re-cementing the well with thin foil placed under the flange of the well. This cement is not placed under this flange, but only on the outside of the cylinder of the well. In attaining the height of the section of the lens (shown in dotted lines in fig. 3), it is best to rest this in a hole

4.



in a plate C, D, placed on the resonant box, and then place the plate with the well on top of the lens. Small corks may be placed between the plates to prevent too much motion of the well around the spherical surface of the lens.

Simple forms of Spherometers with which the well is used.—Other and simpler forms of the well-spherometer suggest themselves. They may be worth the recording, as they may be considered useful by those desiring only approximate measures with simple and inexpensive apparatus.

Fig. 4 shows a form in which the tripod is replaced by a hollow cylinder carrying in its axis a micrometer-screw. The figure explains itself. The micrometer-screw may be replaced by a graduated rod sliding along a fixed vernier, or, a rod may be used without graduation, and two marks cut on it by a sharp edge drawn along the upper surface of the top of the cylinder. One of these marks is made when the point of the sliding-rod touches a plane closing the bottom of the cylinder; the other when the rod rests on the spherical, or other surface, to be measured. The distance separating the marks thus made is then measured with a micrometer-microscope.

Fig. 5 shows how the common micrometer-screw calipers can be used to determine the radius of curvature. With it we measure the united thickness of the well *w* and the plate *p*, cemented to its top. Call this measure t. Then we measure the thickness of the lens; call this l. Then the lens covers the bottom of the well, and the thickness of well and plate and lens is measured in this position. Call this t'. Then $(t+l)-t'=$ height of section of lens above plane of mouth of well. If the axes of screw and well coincide, the pressure of the micrometer on the lens tends to center it in the well. If the plate covering the well be rigid, and the pressures in all the measures be made as equably and as gently as possible, one can thus get the height of the section of the lens to $\frac{1}{1000}$th of an inch. The same measures can be made with the vernier-calipers.

5.

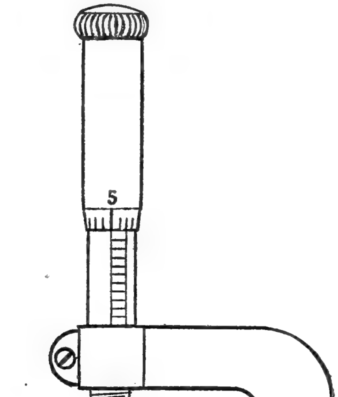


Fig. 6 shows a simple optical method in which the well is used. The well W, is placed with the plane of its mouth vertical. The well is attached to a stand whose base is firmly screwed to the table. A rod, *r*, slides neatly through a hole in the plate closing the back of the well. Hinged to the top of the back of the well is a mirror *m*, and this is pressed against the point of the rod *r*, by a delicate helical spring. When the point of the rod *r*, touches a plane which closes the mouth of the well, the plane of the mirror is vertical. A beam of light from *o*, falls on the mirror and in the present position of the latter the beam is reflected back on *o*. By placing two or three plates of known thickness between the plane covering the mouth of the well and the point of the rod *r*, the beam *m* A, is reflected upward on a vertical scale A, B. The linear values on this scale of equal parts may be determined from these measures. The tilt of the mirror can be measured by observing in a telescope, placed on the line *o m*, the reflection of the scale from the mirror *m*. The amount of motion of the rod against the mirror is as the tangent of the angle of rotation of the mirror, and the reflected beam moves over a space equal to twice its horizontal distance from the screen into the tangent of angle of tilt of the mirror. It is evident that the height of the section of the lens, L, contained within the mouth of the well can thus be measured.

6.

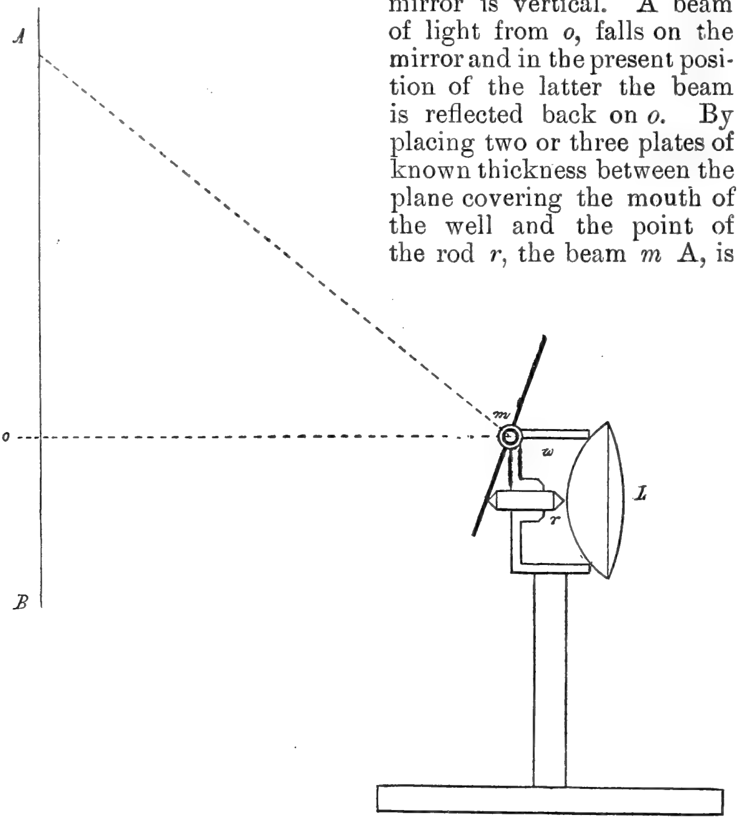
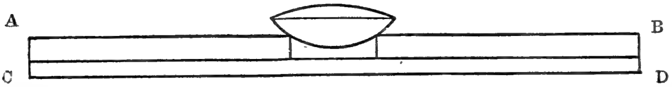


Fig. 7 shows how, with a compound microscope, having its fine adjustment screw furnished with a micrometer-head, we can measure with a well of small diameter the radii of curvature of very small lenses. A, B, is the plate with the well of small diameter. This plate rests on another plate, C, D, with a fine scratch on its upper surface, in the center of the bottom of the well. We first place a piece of thin glass, with a fine line on it, on the top of A, B, with the surface carrying the line resting on the top of A, B, and focus on this line and then take the reading of the screw-head. This plate is then removed and we focus on the line at the bottom of the well, and again take the reading. The difference of readings gives us the depth of the well. Then the lens, which has a fine mark on it where its principal axis cuts its surface, is placed on the glass plate C, D, and the microscope is focussed on the fine mark on the top of the lens, and the reading of the screw taken. The lens is now removed and the microscope is focussed on the fine line on C, D, and the reading of screw is taken. The difference of these readings gives the thickness of the lens. The lens is now placed, as shown in figure 7, covering the top of the well. The line on the top of the lens is again focussed and the reading taken. Then the lens is removed and the microscope is focussed on the line at the bottom of the well, and the screw-head reading taken. Call this measure t'; the depth of the well t, and the thickness of the lens l. Then $(t+l)-t'=$ the depth of the section of the lens below the top of well; and as the radius of well is known, we can compute the radius of the lens.

7.



ART. VIII.—*On some general terms applied to Metamorphism, and to the Porphyritic Structure of Rocks*; by JAMES D. DANA.

A. METAMORPHISM.*

THE ordinary methods of metamorphic change recognized in geology are the following:

(1) The development of a crystalline condition in the original materials; recently shown by Törnebohm, Sorby, Irving and

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* The terms applied to metamorphism are considered in the Presidential Address of Professor T. G. Bonney before the Geological Society of London, in February last; but the copy of the address did not reach the author until June 22, when this paper was just going to press. It does not call for any change in the remarks here offered.

Van Hise to be a development of the grains into crystals or larger crystalline grains by external additions made conformably to the crystallographic axes of the original grains.

2. A change from one paramorphic state to another: as from augite to hornblende, from aragonite to calcite, etc.

3. A change through chemical transformation: as that of chrysolite and other species to serpentine; a portion of a dolomite with included or intruded silica to tremolite, etc.

The last of these methods has been styled *metasomatic* (signifying change in *body*) to distinguish it from change under the first method, to which the word *metamorphic* is accordingly restricted. But this new term is not specific as to *kind* of change; and it applies as well to the second method. A term expressing the *chemical* nature of the change is desirable, and such a descriptive term is *metachemic.* Substituting this we may have the following three descriptive terms for the three methods of metamorphism: I. The *Crystallinic;* II. the *Paramorphic;* III. the *Metachemic.*

Messrs. King and Rowney, some years since, applied the term *methylosis* (meaning change *in substance*), with the adjective *methylotic*, to chemical metamorphism. But metachemic is more simple and intelligible; and priority can put in no claim against a change for the better where such terms are concerned.

By the above scheme, we have the term *metamorphism* as the general title, instead of giving it up to the first method. Each of the three methods involves change in *form.* Paramorphic change is, eminently and specifically, change in form; and metachemic is at least as much so, though complicated with change of other kinds; while change by the first method involves the minimum amount, since, as we now know, the original crystallization remains unaltered, and is only built upon after its own laws. Moreover, the first and third processes,—the most unlike,—are essentially one in agency; the alkaline siliceous waters that build out a quartz crystal, sufficing in some cases (consecutively, if not simultaneously) to convert feldspar into mica, and make other chemical transformations. A common name for the whole is demanded; and *metamorphism* has the necessary comprehensiveness and flexibility in signification and also in its usage in other departments.

In a case of metamorphism, two of the processes of change have often gone on at once, if not the three. For example: the 1st and 3d have worked together in making a tremolitic dolomite; so also in making a mica schist, in which, as proved by Van Hise in his excellent paper (last volume of this Journal) the mica is largely or wholly derived from feldspar, while the quartz grains become enlarged by the 1st method; the 2d and 3d, in the change of an augitic rock to a hornblendic, *whenever* iron oxide or other ingredient is at the same time set free, as has often happened, this indicating that a change in constitution accompanied the paramorphic; the 1st and 2d, in the metamorphism of a common limestone to a crystalline limestone (calcite), supposing such a limestone to be (as it usually is) partly aragonite; and so on. In the derivation of a hornblendic rock from a sedimentary rock, the metamorphism would ordinarily be *metachemic;* but if from an augitic rock, paramorphic in part if not wholly.*

B. PORPHYRITIC STRUCTURE.

Petrography has such names as *felsite-porphyry*, *diabase-porphyry*, *quartz-porphyry*, *augite-porphyry*, etc.; the first two, and others like them, implying that the rocks named are *porphyritic* with crystals of some kind of feldspar; the third, that *some* kind of rock is porphyritic with crystals of quartz; the fourth that some kind of rock is porphyritic with crystals of augite. It has also the name *orthophyre*, for a porphyritic rock having orthoclase in crystals; *augitophyre*, as an equivalent of augite-porphyry; and so on.

It is now generally admitted that the porphyritic character is of trivial value in petrography; that it marks off only *varieties*, and therefore cannot, in any right scientific system, be the name of a group of rocks. For the designation of varieties its recognition is important. Moreover, for this purpose, the precise feldspar or other mineral that constitutes the crystals should be indicated in the qualifying term. The following words, based in plan on such terms as *orthophyre*, *augitophyre* and the like, may well be applied to porphyritic varieties, whatever the kind of rock:

Orthophyric,	when the crystals	are	Orthoclase.
Oligophyric,	"	"	Oligoclase.
Labradophyric,	"	"	Labradorite.
Anorthophyric,	"	"	Anorthite.
Leucitophyric,	"	"	Leucite.
Nephelophyric,	"	"	Nephelite.
Augitophyric,	"	"	Augite.
Chrysophyric,	"	"	Chrysolite (Olivine.)
Quartzophyric,	"	"	Quartz.

Granite, gneiss, mica schist, syenyte, felsyte, trachyte, rhyolyte, obsidian, are often *orthophyric*; felsyte, rhyolyte, dioryte,

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* The terms *metapepsis* and *paroptesis* have been proposed by Mr. Kinahan of Ireland for, respectively, "regional" and "contact" metamorphism. *Contact* is an objectionable word; but *local* is good; for it includes changes due to heated emanations and other conditions where there are no contacts. *Regional* and *local* describe the conditions well, and have been used for a dozen years at least in this country; and why we need go to the Greek for two words is not clear.

dacyte are often *quartzophyric;* in addition to true augite rocks, trachyte, andesite, etc., are sometimes *augitophyric;* different diabases or dolerytes and basalts are *labradophyric*, *anorthophyric*, *augitophyric* or *chrysophyric*; and the same specimen is often both augitophyric and chrysophyric, and sometimes also labradophyric. In a similar way *sphærophyric* may be applied to a crystalline rock containing spherulites or concretions of any kind, distinguishing the structure, thus, from concretionary by concentric deposition, or that common in uncrystalline rocks.

This list of adjectives can be extended if precision in the description of rocks requires it.

SCIENTIFIC INTELLIGENCE.

I. PHYSICS AND CHEMISTRY.

1. *On a new Absolute Electrometer.*—BICHAT and BLONDLOT have presented to the French Academy a new absolute electrometer, based on the attraction of two concentric cylinders, which is easy to construct and which gives continuous indications. An insulated hollow cylinder of metal is connected to the point whose potential is to be measured. A second cylinder is suspended, concentrically within the first, from the arm of a balance, which, is connected to the ground. A third cylinder slightly larger than the second, encloses its lower third and projects considerably below the first and outer cylinder. This cylinder, as well as a metallic screen between the cylinders and the balance beam, is connected to earth. The first or outer cylinder exerts upon the second or suspended cylinder an attraction upward. These two constitute a condenser, the length of the former in relation to the latter being such that in the middle section the equipotential surfaces between them are concentric cylinders and the lines of force radii; while above and below this the distribution varies. If now the suspended cylinder rises above the enclosing third cylinder by a small amount, the change in distribution may be considered to consist of a simple elongation of the uniform portion, the superior portion where the distribution is irregular being simply displaced. If F be the upward force on the suspended cylinder and dz its displacement, the work done by the electric forces is Fdz. But this work is equal to the increase of the energy of the system; and this is proportional to $\frac{1}{2}QV$, in which Q represents the increase of charge and V the potential of the outer cylinder. But $Q=CV$, the product of the capacity of a portion of the cylindrical condenser of height dz by the potential; and this capacity is equal to $\dfrac{dz}{2\log\dfrac{R}{r}}$, in which R and r are the radii

of the inner and outer cylinders respectively. Whence

$$Fdz = \frac{V^2 dz}{4\log\frac{R}{r}} \quad \text{and} \quad V^2 = 4F\log\frac{R}{r}$$

By measuring R and r in centimeters and F in dynes, V will be obtained in absolute C. G. S. units. To measure F, known weights are placed in a small scale pan above the suspended cylinder until equilibrium is obtained. This value in grams is converted into dynes by multiplying by g. The oscillations of the balance-beam are damped by means of a cardboard disk attached to it in place of the second pan and movable within a slightly larger cylindrical vessel of glass. Since within certain limits the force is independent of the position of the inner cylinder, a mirror may be attached above the knife edge and the displacements read with a telescope and scale; their value in dynes being obtained by multiplying the constant of displacement by the tangent of the inclination angle. This constant is determined experimentally once for all, by noting the angular displacement produced by known weights when the electrometer is not charged. Calculation shows that in the actual instrument as constructed, a want of coincidence of 3^{mm} between the axes of the cylinders changes F by only 0·003 of its value. A slight correction may be made for the stem of the inner cylinder. The results given by the apparatus are satisfactory.—*C. R.*, cii, 753–756, March, 1886.

G. F. B.

2. *On the Influence of Temperature on the Heat of Chemical Combination.*—Because of the rudimentary character of our knowledge of the influence exerted by temperature upon the heat of chemical combination, PICKERING has undertaken to investigate it, by measuring this heat of combination within the limits of ordinary atmospheric temperatures, about 25°. Since hydrated salts afford many instances of small energy of combination, and since such substances would be most likely to exhibit a variation in the heat of their formation within these narrow limits, these salts were chosen for the investigation. Whenever a salt is dissolved in water, the difference between the heat of solution in the anhydrous and hydrated states gives the heat of combination of the salt with its water of crystallization, provided the heat absorbed in the conversion of the solid water into liquid water in the second case, is subtracted from the latter. The author finds "that the relation between the constituent portions of the molecule of a complex solid undergoes a series of modifications as the temperature changes, the result of which is that the variations exhibited in the heat of combination, and consequently in the specific heat also, being conditioned by a different order of circumstances at different temperatures, exhibit irregularities of a very marked character." The summary and conclusions of this research we give in his own words: (1) The heat of dissolution of a salt at different temperatures is not represented by a straight

line, but by a curve, or generally by a series of curves. (2) Each of these curves probably indicates the formation and existence of some fresh hydrate in the solution. (3) The formation of higher hydrates as the temperature rises would not appear to hold good when we approach a temperature which is near the melting point of the solid hydrated salt, as in the case of sodium sulphate. (4) From the constant variations in the thermal phenomena attending dissolution at different temperatures, it follows that the specific heats of saline solutions exhibit similar variations, remaining constant, or even varying at a uniform rate, throughout very limited ranges only. (5) The heat of combination of a salt with its water of crystallization in the solid state undergoes similar series of changes. (6) From this it follows that the specific heat of such a salt is not a constant quantity, and that it is not exactly equal to the sum of that of the anhydrous salt and the solid water present, but is generally somewhat less. (7) The general tendency between 2° and 23° is toward an increase of the energy with which the water is combined. (8) Any temperature at which a higher hydrate is formed by a salt in solution is marked by a *decrease* in the heat of combination of the salt with its water of crystallization in the solid state. (9) The heat of combination of two sulphates to form a double salt is subject to variations of the same nature as that of the combination of a salt with water. (10) The variations in the heat of combination of the two salts is attended by variations of an opposite sign in the heat of combination of the double salt and the water combined with it. (11) Most of the salts here investigated show some points of similarity in the curves which they yield, but each possesses specific peculiarities. (12) The peculiarities exhibited by a single salt appear to be reproduced to a certain extent in the double salts which they form,—illustrated by the rise in the curves of both the magnesium salts at about 22° and the character of abruptness displayed in the case of both the copper salts."—*J. Chem. Soc.*, xlix, 260–311, May, 1886. G. F. B.

3. *On the Hypochlorites of Ethyl and Methyl.*—Some time ago in a preliminary paper, SANDMEYER showed that by mixing alcohol with strong aqueous hypochlorous acid, hypochlorous ether was separated as a yellow oil. The ready decomposition of the acid, however, caused the yield to be very small. The author now finds that almost the theoretical quantity can be obtained if the alcohol be mixed with caustic soda solution and chlorine gas be passed through the liquid, well cooled. For this purpose, a glass tube 3^{cm} in diameter and 40^{cm} long, drawn to a narrow neck at top and having a glass stopcock at bottom, placed in a Liebig condenser, was three-quarters filled with a solution of one part sodium hydrate and one part alcohol in nine parts of water, and, being slightly inclined from the horizontal, chlorine gas was passed in through the stopcock, the whole being cooled by a current of water. The gas was readily absorbed, the solution became yellow and turbid and a layer of yellow oil collected on the

surface. Just before the gas ceased to be absorbed the operation was stopped, the salt solution drawn off and the ethyl hypochlorite collected and dried. Repeating this experiment with methyl alcohol, a point was soon reached where the gas seemed no longer to be absorbed. But the gas evolved was not chlorine, since a test-tube of it violently exploded on the approach of a flame. Passed, first through a calcium chloride tube and then through a cooling mixture of ice and salt, it condensed to an exceedingly volatile yellow liquid of penetrating chlorine-like odor, which could be mixed with methyl alcohol without decomposition, and a drop of which on a porcelain surface exploded like dynamite on touching it with a flame, shattering the vessel. Its boiling point was fixed at 12° under a pressure of 726^{mm}. Analysis proved its formula to be CH_3OCl. Sulphurous oxide unites directly with methyl hypochlorite, forming methyl chlor-sulphonate, $CH_3 . OSO_2 Cl$, a colorless liquid with a powerful odor, boiling between 132° and 133°.—*Ber. Berl. Chem. Ges.*, xix, 857–861, May, 1886.

G. F. B.

4. *On the Existence and Formation of Nitrates in Plants.*—BERTHELOT and ANDRÉ have conducted, at the Meudon station of plant-chemistry, an elaborate series of investigations on the existence of nitrates in plants, the results of which they have published in four separate memoirs, entitled respectively: Methods of analysis; the universal presence of nitrates in the vegetable kingdom; the study of nitrates in the different parts of plants and at various stages of growth; and an examination of the various sources from which these nitrates may come. They find that *Borrago officinalis*, and the *Amarantaceæ*, of all the large variety of plants examined, contain most nitrates; that the stem contains most, and the roots next; that nitrates increase from germination until just before flowering, and then diminish; increasing again however after the reproductive function is completed and even after the death of the plant. Grown on a hectare of surface, *Borrago officinalis* gives 120 kilograms of saltpeter; *Amarantus bicolor*, 128 kilograms; *A. caudatus*, 140 kilograms; *A. pyramidalis*, 163 kilograms; and *A. giganteus*, 320 kilograms. As to the origin of this nitrate, four sources may be suggested: (1) the fertilizers used, (2) the soil, (3) the nitric acid of the atmosphere and (4) its formation in the plant itself. The first is excluded by the fact that the manures used contained only a trace of nitrates. With regard to the soil, analysis showed that the earth over a hectare, to the depth of 0·325 meter contained 54 kilograms potassium nitrate; which is less than half that contained in the *Borrago* grown on this surface, and less than one-sixth of that in the gigantic Amaranth. Moreover direct experiment showed that the nitrates in the soil did not perceptibly increase during the growth in it of the plant; and that, even when washed out of the soil by the rain, the quantity in the plant remained sensibly the same. As to the atmosphere, analyses made at the Montsouris observatory showed that the nitrate contained

in the rain which fell during the season, amounted upon a hectare to 4·4 kilograms only: scarcely one-twentieth of that in the soil. The authors hence conclude that the formation of nitrates in plants is an established fact and seems to result from the special action of a more general function of the cellules, the function which gives rise to oxidations; that is to say, the same function which produces carbonic acid and carbonates, oxalic, tartaric, citric, malic and other peroxygenized acids. The further investigation of this function is already in progress at Meudon.—*Ann. Chim. Phys.*, VI, viii, 5–128, May, 1886. G. F. B.

5. *On the earth Yα and Mosandria.*—Among the earths of samarskite which accumulate in the middle fractions, **Crookes** has found one (or perhaps a group) giving a well defined phosphorescent spectrum in the radiant matter tube, consisting of nine bands, of wave-lengths 644·6, 641·5, 618·9, 609·4, 597·0, 567·6, 561·3, 549·5 and 540·6. When sufficiently pure, the earth giving this spectrum presents the characteristic properties of that discovered by Marignac and called Yα; as the author had proved by a comparison of his own material with a sample of Yα sent to him by Marignac. A sample of mosandria, prepared by Lawrence Smith, sent to Crookes by Marignac gave a phosphorescent spectrum showing that it is not a single substance and that it contains the earth yttria.

In the following paper, **Lecoq de Boisbaudran** gives the results of his examination of a specimen of impure mosandria from the laboratory of the late Lawrence Smith, sent to him by Dr. Marvin of Louisville, Ky. It contained much didymia and samaria; and on removing these by fractioning with ammonia, the residue gave brilliantly the electric spectrum of Yα, so that at first thought, the author considered this the purified material which Smith described. Marignac however called his attention to the fact that Smith described mosandria as a highly colored orange-yellow oxide, while Yα as prepared by Marignac is nearly colorless, and would probably be white if pure. In fact, the earth obtained from the crude mosandria is dark orange-yellow in color and gives the phosphorescent bands Zα and Zβ, the latter predominating. Hence it appears probable to the author that the mosandria of Lawrence Smith consists of a mixture of the earths Yα and terbia, the latter in excess; thus agreeing in opinion with Marignac.—*C. R.*, cii, 646–648, March, 1886. G. F. B.

6. *On the Spontaneous Polymerization of volatile Hydrocarbons at ordinary temperatures.*—Sir H. E. **Roscoe** has called attention to the production of a solid crystalline hydrocarbon $C_{10}H_{12}$ from the most volatile fraction obtained by decomposing crude phenol at a red heat. This fraction boiled between 20° and 40°; and on standing several weeks was converted into a solid polymer, fusing at 32·9° and distilling at 160° to 170°, though with decomposition. Its sp. gr. was 1·012 at 17·5° and its vapor density was 4·39 and 4·57 in two experiments. It oxidizes to a yellow resin in the air and yields a nitro and a brom-derivative.—*Liebig's Annalen*, ccxxxii, 348–352, April, 1886. G. F. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *The Cretaceous Flora of North America.*—An abstract of a paper by Professor NEWBERRY on the Cretaceous Flora of North America, in the Trans. N. Y. Acad. Sci., No. 5, 1886, mentions the discovery of great numbers of leaves of Angiosperms in the Raritan or Amboy clays of the New Jersey Cretaceous, and states that the author has already fifty quarto plates of drawings ready for the engraver. The clays are largely explored for making brick and pottery. Professor Newberry regards the clays as the equivalent of the western Dakota group, the Atane beds of California, and of the Upper Greensand of England. The Angiospermous leaves, of which there are fifty to sixty species, pertain to the genera *Liriodendron*, *Magnolia*, *Sassafras*, *Aralia*, *Celastrus*, *Celastrophyllum*, *Salix*, and what Heer has called *Hedera*, *Ficus*, *Diospyros*, *Juglans* and others. With these, many specimens have been found of a helianthoid species of the Compositæ, *having a flower three to four inches* in diameter, in which the ray florets (?) were scarious and persistent like those of Heliochrysum.

There are also fine species of two genera of Leguminosæ, Bauhinia and Hymænea, not before reported from the North American Cretaceous. The specimens gathered include also about a dozen species of Conifers, as many Ferns, and two or three Cycads. "Taken together," says Professor Newberry, "this flora is of surprisingly high botanical rank, quite as much so as that obtained from any Tertiary strata." The Mill Creek beds of British America are referred by him to the same horizon; and the Peace River are made the equivalent of the Chalk.

From the Potomac clays of Virginia, a still older Cretaceous flora, supposed to be Neocomian, has been found by Professor Fontaine, where "a large number of species of Cycads, Conifers and Ferns occur along with a few Angiosperms." The plants of beds of the Queen Charlotte Islands are referred to the same horizon.

2. *Periods of enlargement and diminution in the Glaciers of the Alps.*—Mr. FOREL reports, from the data which he has collected with much care, that there have been this century five periods in the Alpine glaciers; of enlargement from 1800 (?) to 1815; of diminution from 1815 to 1830; of enlargement from 1830 to 1845; of diminution from 1845 to 1875; and of enlargement again from 1875 onward. He remarks further that these periods correspond with those deduced by Mr. C. Lang for the variations in precipitation and temperature of the air; and consequently, that the enlargement of the glaciers has gone forward in the cold and rainy period and the diminution in the warm and dry.—*Archives Sci. Phys. Nat.*, May 15, 1886, p. 503.

3. *Maps published by the U. S. Geological Survey.*—The Geological Survey, in carrying forward the preparation of a geologi-

cal atlas of the United States ordered by the General Government, has had topographical surveyors in the field, in different parts of the country; and the forty-five maps now issued are part of the results thus far completed. They cover portions of Utah, Nevada, Arizona, Texas, Missouri, Kansas and Alabama. Each comprises about one degree in latitude and the same in longitude, and measures 17 to 18 inches by 12 to 14. Altitudes are marked by contour lines, with the addition of numerals on the peaks or higher points, and the rivers are printed in blue. The maps are finely engraved, of convenient size, and beautiful in appearance; and when completed and supplied with geological coloring and details, will be esteemed at home and abroad as very important work well done. The country is large and the expense will be large; but the great work should be carried through to its full completion whatever the cost.

4. *Stromatopora.*—Dr. C. ROMINGER criticises the paper of Nicholson and Murie on the structure of Stromatopora, in the Proc. Nat. Sci., Philadelphia, of 1886, pp. 39–56.

5. *Palæontologica Indica.*—Numerous Bryozoa, Annelida and Echinodermata of the Productus Limestone in the Salt Range, are described by Dr. Wm. Waagen in a part of the quarto publications of 1885, and beautifully illustrated on plates 87 to 96. All the plates but two are devoted to the Bryozoa. The author excludes from the Bryozoa the genera Chætetes, Stenopora, Monticulipora, regarding them as probably belonging with the tabulate corals, and includes therefore only two families, the Fenestrellidæ and Thamniscidæ.

6. *Microscopic characters of some specimens of devitrified glass;* by D. HENMAN and FRANK RUTLEY, (Proc. Roy. Soc. 1885, p. 87).—The authors describe the effects obtained by microscopic examination of various specimens of devitrified glass. Devitrification was obtained by covering the floor of the kiln with 2½ inches of sand, putting on this the glass, and then a layer of sand 3 and 6 inches thick. By slow heating, in six days the glass had become dull red, and in six more a bright red, without fusion. This temperature was maintained for twelve days and then the kiln opened and quickly cooled. In other experiments, the time was varied. It was found that with heating for twenty to thirty days, as above described, the glass was thoroughly devitrified; that if the heat was kept below dull red heat, or about 650° F., there was no devitrification; and if cooled immediately after heating to 650° F., allowing four hours for the cooling, the devitrification was slight and mostly on the surfaces. The devitrification goes on from the surface inward. When least complete, stellate or radiating crystallites are formed; and when a little more so there is usually a tendency to a spherulitic structure; and when complete, it is generally a mass of more or less distinct divergent groups, separated sometimes by an angular outline. There are in some cases spherulites, with or without a radiated structure.

7. *E. O. Ulrich's Contributions to American Palæontology,* Vol. I. Cincinnati, 1886.—Mr. Ulrich in his prefatory remarks

on the first page of this first number of his Palæontological Contributions, after alluding to the difficulties in the way of publication of papers requiring illustrations, announces that to make himself independent, he proposes to establish a series of private publications, under the above title, to appear as material demands it. He expresses his indebtedness to Mr. G. K. Greene of New Albany, Indiana, for his generous financial aid with reference to the number now published. Paleontologists and others may aid his enterprise and the science by subscribing for the Journal. This first number contains a valuable paper by Mr. Ulrich, consisting of descriptions of New Silurian and Devonian Fossils (Corals, Mollusca, etc.), which is illustrated by three excellent plates.

8. *Class-book of Geology;* by ARCHIBALD GEIKIE, LL.D., F.R.S. 516 pp. 12 mo., illustrated with woodcuts. London, 1886, (Macmillan & Co., N. Y.)—In this "Class-book of Geology" Dr. Geikie presents the science in a simple and readable form, for the benefit especially of young students in the department, and also for the general public. The operations going on over the globe are explained by various examples and then applied to the illustration of the events in geological history. From an account of the action of water in rivers and oceans and their results, the work passes to the subject of volcanoes; then devotes many pages to minerals and rocks; and afterward treats of stratification, volcanic eruptions, mineral veins, fossils, and the general system of progress through the geological periods. The illustrations are good, and in part from the note-book of the able author.

9. *Ancient Herbaria. Histoire des Herbiers*, par le DR. SAINT-LAGER. Paris, Baillière et fils, 1885, pp. 120, 8vo.—The author of this treatise shows us that only in the seventeenth century did the word *herbarium* acquire its present meaning, that of a collection of pressed specimens of herbage and flowers, prepared for botanical uses. The *Herbarius* of the Romans was the herb-collector. *Herbarium* down through the sixteenth century was the common name of a *Historia Plantarum* or other botanical treatise. Next it came to mean a collection of *simples*, a sort of museum of the actual herbs, roots, fruits, etc., used in medicine or the arts. Sprengel, in his *Historia Rei Herbariæ*, in telling of the botanic garden which Brassavola established on an island of the Po near Ferrara, adds "herbarium ipse collegat ditissimum." But the collection was one of simples, as is well known from contemporary evidence, not of botanical specimens. These came after the botanic garden, naturally, and the first recorded name of such a collection is by Adrien Spiegel (Spigelius), in 1606—that of *Hortus hiemalis.* When plants are all dead in winter, he says, the only resource is to botanize in *horti hiemales*, that is, in books filled with dried specimens stuck fast to the leaves. *Hortus siccus* soon came to be the name, lasting down to our days. But Tournefort brought in the now prevalent name before 1700, defining it thus: "*Herbarium sive hortum siccum appellant collectionem*

plantarum exsiccatarum que in codicibus vel capsis asservantur, ut quavis anni tempestate inspici possent.

Whether the first-known maker of such a collection of pressed specimens was Ghini, of Pisa, or John Falconer, an Englishman or probably a Scotchman, seems unsettled. Anyhow, it is odd that neither of them has had a genus of plants named for him by any of the long line of their successors.

The history of the most ancient herbaria known has now been carefully written up by M. Saint-Lager, of Lyons. Of John Falconer's herbarium it is only known that it was admired by Italian botanists at Ferrara in the year 1545, and was examined by Turner at London, on the owner's return to his native country. The most ancient herbaria now extant, or partially so, are those of Aldrovandi, commenced in about the year 1553 (and which contains as many as 5,000 specimens in seventeen volumes); of Girault, of Lyons, which bears the date of 1558, and of Cesalpin, which bears the date of 1563. The first of these is preserved at Bologna, its proper home, although it was once taken to Paris; the second is at the Jardin des Plantes; the third is at Florence. Next in chronological order is that of Rauwolf (who died in 1596), preserved at Leyden; then that of Caspar Bauhin (who died in 1613), preserved at Basle in excellent condition. The curious reader will find a full account of these herbaria and much interesting lore besides, in M. Saint-Lager's essay. A. G.

10. *The Journal of the Linnæan Society, Botany,* vol. xxii, contains unusually interesting papers, to which, however, we can make only brief reference. The first paper is Mr. John Ball's *Contributions to the Flora of the Peruvian Andes*, etc., of which an extended review has already been given to our readers. In the succeeding number (pp. 137–168), under the title of *Notes on the Botany of Western South America*, Mr. Ball, after sketching the features of the climate of the seaboard from Panama to the Chonos Archipelago, specifies the principal plants he collected at several points, characterizing also a few new species, and adding various critical annotations and interesting suggestions. Mr. Bolus gives a second part of his *Contributions to South African Botany*, relating to the *Orchideæ*. The Rev. George Henslow follows with his suggestive *Contribution to the Study of the relative effects of different parts of the Solar Spectrum on the Transpiration of Plants.* He confirms Weisner's results, adding "somewhat tentatively," the "additional fact that yellow light has a retarding influence upon transpiration." Mr. Francis Darwin here publishes the results and many of the details of his researches —begun in connection with his lamented father in 1878—*On the Relation between the "Bloom" on Leaves and the distribution of the Stomates.* The point is, that one function of bloom is to be found in the protection of the stomata from wet, which would interfere with the prompt ingress and egress of air. It is familiarly known that in very many leaves the stomates occupy the lower surface, either exclusively or most largely, and this is the face least exposed to rain. But it appears that whenever the

upper surface has a bloom, and so to a considerable extent sheds the rain, there is a strong tendency to the accumulation of stomates on that surface. A paper by Mr. Ridley on *Orchids from Madagascar*, and a readable narrative by C. Baron Clarke, of *Observations made in a Journey to the Naga Hills, in Upper India*, need not be remarked upon. A remaining article, *Contributions to the History of certain species of Conifers*, by DR. MAXWELL T. MASTERS, pp. 169–212, with nine plates and copious figures in the letterpress, is of general interest and importance. The illustrations and much of the text are reproduced from the Gardeners' Chronicle in this more convenient and accessible form. The species here discussed, with which we in this country are most concerned, are *Abies amabilis*, *A. grandis*, *A. concolor*, *A. subalpina*, and *A. nobilis* with *magnifica*, the observations of Engelmann and Sargent, as well as those of Hooker, supplemented by Dr. Masters's own critical studies. We trust that this paper is only the first of a series.

Volume xxiii opens, and the first number (150) is filled, with a paper of much botanical importance, viz: *An Enumeration of all the Plants known from China proper, Formosa, Hainan, Corea, the Luchu Archipelago, and the Island of Hongkong; together with their Distribution and Synonymy*, by FRANCIS BLACKWELL FORBES, F.L.S., etc., and WM. BOTTING HEMSLEY, A.L.S., etc. This first portion extends from the *Ranunculaceæ* to the *Ternstrœmiaceæ*. It will fill the volume, and when completed will be separately issued, with introduction and summary, under the title of *Index Floræ Sinensis*. A. G.

11. *Heterogeneous Grafting.*—Strasburger, in the Berichte der Deutschen Bot. Gesellschaft, vol. iii, records some curious results of his experiments in intergrafting various herbaceous *Solanaceæ*. Thus, he successfully grafted species of Stramonium, and common Tobacco plant, Henbane, Atropa Belladonna, and Petunia upon the common Potato plant. Grafts of *Datura Stramonium* and *Nicotiana Tabacum* took remarkably well, the plants growing freely and coming into flower. Tschudy, however, long ago had grafted *Lycopersicum* upon a Potato stock, and so had gathered potatoes from the bottom and tomatoes from the tops of the same plant; but this is not so extraordinary, the two plants being no essentially congeneric.

The most remarkable result of Strasburger's trials was that, when *Datura Stramonium* was grafted upon a Potato plant, the potatoes borne by the latter, to all appearance normal, were found to be impregnated with atropine. He does not say whether these grafted into *Nictiana Tabacum* had their tubers infected with nicotine. A. G.

12. *Contagious diseases of Insects.*—A number of the Bulletin of the Illinois State Laboratory of Natural History, recently issued contains a very interesting paper on this subject, prepared by S. A. Forbes, from careful personal studies and experiments. It constitutes Article iv, in Volume ii, of the Bulletin.

13. *Proceedings of the Davenport Academy of Natural Sciences.* Vol. iv, 1882–1884. Davenport, Iowa, 1886.—This new volume of 348 pages, contains papers on the plants of Iowa; a new Arctostaphylos from California; the genus Chorizanthe; on a new genus and species of Blastoid, by C. Wachsmuth; and on new species of Blastoids, by W. H. Barris, with two excellent plates; but it is occupied chiefly with ethnographic papers which are illustrated by many figures of the pottery among the ancient Indians of the Mississippi Valley. It contains also a biographical sketch of Dr. Robert James Farquharson, an active member of the Davenport Academy of Sciences.

14. *Annalen der k. k. Naturhistorischen Hofmuseums redigirt von Dr. Franz Ritter von Hauer.*—Roy. 8vo. Vienna.—This new Journal was commenced with the current year, under the editorial charge of Dr. von Hauer, who now is Director of the Royal Museum at Vienna. The second number contains the following papers: on the Miocene Pteropods of Austria-Hungary by E. Kittl; on new and rare Antilopes in the Museum, by Dr. Fr. Kohl; on the Paleozoic Insects, by Dr. Fr. Brauer; on Specific Gravity determinations of Minerals, by Dr. V. Goldschmidt; on the Crystalline form of Tellurite and Valentinite, by Dr. A. Brezina. The subjects are illustrated by seven plates, besides woodcuts in the text.

V. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science.*—The thirty-fifth meeting will commence at Buffalo, N. Y., on the 18th of August. This will be the third welcome of the city to the Association. The circular of the local committee states that the high school, recently improved and enlarged, has been placed at the disposal of the Association for the daily sessions; and that the offices of the permanent and local secretaries, as well as those of the different committees, will be located in the building. Buffalo is one of the leading railroad centers of the United States; and, through the committee already eighty railroads, mentioned in the circular, have consented to give reduced rates to members of the Association, eastern roads charging 1½ cents a mile for the round trip, and the western one-third rates. Detailed information as to railroads, hotels, and other arrangements, may be obtained by addressing the Secretary of the Local Committee, Dr. Julius Pohlman. Arrangements are in progress for excursions; and besides, the Botanical Club of Buffalo is arranging an excursion and reception for the botanical members of the Association; and the same with the Entomological Club of Buffalo. The permanent secretary, Professor F. W. Putnam, of Salem, Mass., should be addressed with reference to papers for the meeting.

Flow of water in open channels, pipes, sewers, conduits, etc., with tables based on the formulæ of D'Arcy, Kulter and Bazin, by P. J. Flynn, Civil Engineer. 118 pp. 18mo. New York, 1886 (D. Van Nostrand.)

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Page 78, 23 l. from foot, for HENMAN read HERMAN.

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[THIRD SERIES.]

ART. IX.—*On hitherto unrecognized Wave-lengths;* by S. P. LANGLEY. (With Plates I to IV.)

WE have already* presented a description of the method by which we were able to fix the wave-lengths in the solar spectrum by direct measurement as far as about 23,000 of Ångström's scale. At this point the heat in the solar normal spectrum had become so feeble that it taxed the utmost limits of our capacity in 1881 to measure it; for it will be remembered that we are able to study the prismatic spectrum of the infra-red with comparative ease, because the prism condenses the heat; but the grating greatly diffuses and weakens it, so that, were it due to this cause alone, we should find measures in this part of the grating spectrum enormously more difficult than those in the prismatic. But independently of this, of the heat which belongs to any ray, our grating in general employs not over the tenth part. These causes combine to make the heat in certain portions, where we have been compelled to measure, almost infinitesimal.

We are led to take this labor, not primarily to settle the theoretical questions involved in determining the relation between dispersion and wave-length, (though these are most interesting), but with the object of providing a way which will hereafter enable any observer to determine the visible or invisible wave-lengths of any heat, whether from a celestial or terrestrial

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* This Journal, vol. xxvii, March, 1884.

source, observed in any prism; and thus to gain that knowledge of the intimate constitution of radiant bodies which an acquaintance with the vibratory period of their molecules can usually alone afford us. It is this considerable end,—the opening up to research of the whole unexplored region of infra-red energy, not only from celestial but from terrestrial sources—which will, we trust, justify the labor devoted to the following determinations. It may be hoped that wider interest will attach to our task of demonstrating the character of a certain curve, when it is seen that a knowledge of its true form has ceased to be a matter of abstract speculation only, but will, in connection with what has already appeared, now introduce to us such large regions of research as we have just indicated. Over and above all this, however, we shall find our results also affecting opinion on the theoretical considerations regarding the relation of wave-length and dispersion just alluded to.

In previous communications I have given a representation of the solar heat spectrum terminating near $2^{\mu}{\cdot}7$ or $2^{\mu}{\cdot}8$ and I have stated that while there were feeble indications of solar heat below this point, yet that the solar radiation beyond seemed sensibly cut off, as though below this were a nearly unlimited cold band. I do not mean then, in saying that solar heat sensibly ceases below this point, to say that absolutely none can exist, but that none at any rate does exist sensible to the delicate apparatus with which these first determinations were made, and that none in any case exists of an order comparable with the smaller portions of that already described.

The reader will gather a more clear conception of the difficulty of decision and of the almost infinitesimal amount of this solar heat below 3^{μ}, if it exist, by looking at Plate I in connection with the statement, that if there be any solar heat at 4^{μ}, the highest ordinate representing it on the same scale as that shown on the left of the Plate, would at any rate not occupy the thickness of the horizontal line which represents the axis of abscissæ. However, since we are rather inclined to admit from our final experiments with our latest and most sensitive apparatus, that heat of some kind reappears here near 4^{μ}, whether from the atmosphere of the sun, or elsewhere, insensible to the thermopile, and in any case, if it be real, almost infinitesimal in degree, or of the same order of intensity with that in the lunar spectrum; our statement that no sensible solar heat exists here must be taken under this qualification.

New Apparatus.

The apparatus for the determination of wave-lengths in connection with the flint glass prism has been already described.*

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* See this Journal, March, 1884.

The following is the same in principle, with certain changes to adapt it either to the solar or electric heat. Let S_1 be the first slit, (see Plate III). For solar heat it has doubly moving jaws, controlled by a micrometer screw, while in the case of the electric arc we use a special form of slit surrounded by water, to be directly described. G is the large concave grating. The massive beam A, already described, carries the large rock-salt train S_2, L_1, P, L_2, B. G is fixed at the extremity of the beam, so that its collimating axis coincides with that of L_1, and by means of an automatic apparatus, not shown here, the slits S_1 S_2 are caused to lie always in the same straight line at right angles to G S_1. Under these circumstances, it has been demonstrated by Professor Rowland that the wave-length of light, passing through the slit S_1 to fall upon the grating and there be diffracted to S_2, is directly proportional to the distance S_1 S_2. Accordingly, owing to this extremely simple relation, we are able to state at once what invisible ray or rays are at any moment passing through the slit into our rock-salt train. Our engraving represents the arrangement as fitted up for the heat of the electric arc, which is placed immediately in front of the special nozzle *n* carrying the slit S_1. We wish to employ the arc chiefly in the extreme infra-red beyond the solar heat, and where any heat is excessively minute. The hottest part of the electric arc is found in the pit or crater of the positive carbon, concealed from direct vision, and occupying a space of only 3 or 4^{mm} square, even in large arcs. The carbons then must be inclined in order that a horizontal beam may escape from this almost hidden crater, which owing to its small size, should be brought nearly in contact with the slit, in order to utilize the whole of its very minute area, while in this case the inclination of the carbons will prevent such approach. Experiments with various forms of incandescent-strips and carbons, directed by clock-work in the ordinary position, have proved the necessity of adopting the special device by which we have finally overcome these difficulties. Figure 1, Plate III, shows in section and in front view, one-half full size, a special slit, conical in form, around which a current of water is forced to circulate. Figure 2 shows the carbons on a smaller scale and the apparatus which permits them to be set at any height, inclined at any angle to the vertical, drawn back or approached to any distance. They are usually placed almost in contact with the special slit S_1, and the need of the water circulation is obvious, were it only to prevent the sides of the jaws of the slit from melting, as they would otherwise soon do. There is however another necessity for this water circulation. The need of a slit which may be artificially cooled for measures in the extreme infra-red of the spectrum from the electric arc, is rendered evident when we state that for these extreme wave-lengths, the arc radiation is comparatively so small, that *the heat from the hottest part of the dazzlingly bright carbon does not very greatly exceed that from a piece of melting ice.* If, then, we are to distinguish here between the radiation which passes through the open slit from the incandescent carbon and that which comes from the adjacent edges of the slit, which inevitably mingles more or less with the former, the difference between the two temperatures must be made as great as possible.

Following now on Plate III the course of the ray from this electric arc, we observe that it falls on the grating G (to be presently described), which spreads it out into not one but many superposed spectra, distributed along the circumference of a circle whose center is at O equidistant from G, S_1, and S_2. For clearer illustration, let us suppose ourselves about to measure the heat in some ray of the visible spectrum (such as that near D_2, whose wave-length is nearly $0^{\mu}{\cdot}6$) and that the line S_1 S_2 is a scale of equal parts. In this case, the beam A will be moved so that while the grating remains at the intersection of N S and G A and normal to the latter, the slit S_2 will be brought close to S_1 in the position $0^{\mu}{\cdot}6$ on our scale of equal parts, whose zero is at S_1. Here, (if we suppose sunlight to be employed,) we shall see a brilliant spectrum filled with Fraunhofer lines crossing the front of the plate of the slit S_2. Beyond this the second, third and other higher orders of spectra are distributed on the circumference of the circle in which S_2 always lies. Were it our only object to discriminate the heat in this particular visible ray, we should not in this case need the slit S_2 or the prismatic train, but could place the bolometer directly at S_2. Since we make the ordinary use of the slit S_2 however, we suppose ourselves to be determining the prismatic dispersion, for a given wave-length, that is, it forms with the prismatic train an approximately homogeneous spectral image at B, which can be viewed, or measured with the bolometer, giving the value of n for a known value of λ. For the mere purpose of measuring the heat in the ray, or determining its wave-length here in the visible part, where there is but a single sensible heat-spectrum, we do not need slit S_2 at all, while the refractive index for a glass prism could be as easily determined as that for rock-salt. Besides this, we should find here a relatively abundant heat and could use so narrow a bolometer as to fix the position by it alone quite accurately. Very different, however, are all the conditions if we wish to measure, for example, a wave-length corresponding to 3^{μ} or 4^{μ} in the *invisible* spectrum and in the new region which we are for the first time exploring. Glass is impermeable to this kind of heat, but with our rock-salt train and with the delicate apparatus previously described, there is little difficulty in discriminating it by the bolometer, where the prism alone is employed, and in mapping the deviation of each spectral ray as shown in Plate III of our paper in this Journal, Jan., 1886. But now that we wish to determine wave-lengths, the conditions are altogether different; for not only the grating enormously expands this part of the spectrum and has cut the heat down correspondingly, just where that heat is itself feeblest, (so that the heat in parts of this region, is something like $\frac{1}{1000}$ part of that in the corresponding prismatic spectrum), but instead of one visible, we have now to deal with numerous invisible, spectra, overlapping ecah other.

Here then the slit S_2 has an additional function to fulfill, namely, with the aid of the prism, to discriminate these invisible spectra from each other. Thus in the position actually shown in the drawing, which corresponds to a wave-length of $3^{\mu}\cdot5341$, i. e., of 35341· of Ångström, we should see the slit covered by a bright spectrum, due to several of the higher orders, while we know that the energy of the wave-length we are seeking is wholly invisible. If we place a pellet of sodium in our electric arc, we shall see the two sodium lines on the slit plate, of which D_2 will fall exactly on the slit, if it be in adjustment; but this sodium line evidently does not belong to the wave-length we are seeking.

There are in fact, passing through the same slit and lying superposed on one another by an unavoidable property of the grating, an infinite number of spectra in theory, of which in this case nearly twenty are actually recognizable, by photography, by the eye, or by the bolometer, and of which, to consider only those where the wave length is equal to or greater than that of the sodium line D_2* we have six spectra as follows:

a.	(visible)	6th	spectrum	D_2 --------	$\lambda = 0^{\mu}\cdot5890$
b.	"	5th	"	$\frac{6}{5}D_2$ --------	0·7068
c.	(invisible)	4th	"	$\frac{6}{4}D_2$ --------	0·8835
d.	"	3d	"	$\frac{6}{3}D_2$ --------	1·1780
e.	"	2d	"	$\frac{6}{2}D_2$ --------	1·7670
f.	"	1st	"	$6\,D_2$ --------	3·5341

It is in this invisible underlying first spectrum, buried, so to speak, beneath five others, of which three are themselves invis-

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* We have heretofore adopted Angström's notation in calling the more refrangible sodium line "D_1" We shall hereafter, however, in conformity with the now more general usage, call this line, whose wave-length in Angström is 5889, "D_2." The corrections to Angström are due to the researches of Messrs. Peirce and Rowland.

ible also, that lies the wave-length we are seeking; consequently, there are (to consider no others) at least six qualities of heat, of six distinct refrangibilities, whose wave-lengths are equal to or greater than that of D_2, which pass simultaneously through the slit S_2. They pass through the prism, and on looking through a telescope occupying the position of the bolometer tube, we shall by suitably directing the arm of the spectroscope see the light from the sixth one at *a*. Its wave-length will be $0^{\mu}\cdot5890$, corresponding to a measured deviation (in the case of the rock-salt prism, of an angle of 60° 00′ 00″ and a temperature of 20° C.) of 41° 05′ 40″. Now on replacing the telescope by the bolometer, the bolometer wire will feel this same ray which the eye has just recognized by its light, and, if the galvanometer be in a sensitive condition, the image will be thrown by the heat off the scale, while a little on either side of this position no indication will be given. The beam and the slit S_2 remaining in the same position, let us next suppose that the bolometer arm is carried toward *b*, in the direction of B. There will be no sensible deflection until it reaches the position *b* in the red, corresponding to a wave-length of $0^{\mu}\cdot7068$, and in the prism to an angle of 40° 33′ nearly, for there is no sensible heat except in the successive images of slit S_2 formed by the prism P in the line PB. Passing farther toward B we come into the heat in *c*, and next to the heat in *d* which is less than $\frac{1}{100}$ that in the direct prismatic image, when no grating is employed.

This was the utmost limit of our power of measurement in 1883, beyond this point radiations from the grating being then absolutely insensible, and the radiation at the point *d* itself being excessively minute, even in the solar spectrum, where the heat, so far as any is found, is as a rule far greater than that in the spectrum of the arc. Accordingly I have elsewhere observed that these measures could be carried on as well by a large electric arc as by the sun; but in fact, owing to the difficulties attendant on bringing the arc, which must be of immense heat, close to slit S_1, and to other causes, the sunlight would be preferable wherever it could be used.

Our observation of June 7, 1882, gave the value of the index of refraction corresponding to $\lambda=2^{\mu}\cdot356$, which was the lowest possibly attainable by our then apparatus. Incessant practice and study, resulting in improvements already referred to, have enabled us finally to measure down to a wave-length of $9\times\lambda D_2$ corresponding to a position much below *f*. We may add that in doing so, it is sometimes convenient to employ a bolometer wide enough to overlap the images in the other adjacent spectra of the higher orders, which we may usually do without confusing them, owing to their feebleness compared with that of the first spectrum in which we are searching.

We usually, however, employ a bolometer of not more than 1^{mm} aperture, and this demands excessive delicacy in the heat-measuring apparatus, since the heat here is, approximately speaking, about $\frac{1}{10000}$ of that in the region between the sodium lines in the direct spectrum of a rock-salt prism. This is near the limit of our present measuring powers with the grating, even when every possible device is used to increase the extremely feeble heat in this part of the spectrum.

We commenced by using an electric arc with carbons 12^{mm} in diameter in the position indicated. These were supplied by an engine of three-horse power; but even in this case the pit of the crater did not nearly cover the very short slit (its length is 8^{mm}). For these last and most difficult measurements, we have been obliged to procure the use of an engine of twelve horse-power and carbons 25^{mm} (one inch) in diameter. With this enormous current the hottest part is not easily maintained in place. To keep it directly in front of the slit we have tried various plans, such as boring out the carbons lengthwise, so as to form hollow cylinders of them, and filling the core with a very pure carbon tempered to the requisite solidity. Ordinarily it will be sufficient however to first form the central crater by a drill. This gives us a persistent crater, whose light, in the position shown in the engraving, filled a slit whose vertical height is 8^{mm}. It is probably the intensest artificial heat ever subjected to analysis.

Bolometer.

The changes in the bolometer since it was first described (Proceedings American Academy, 1881) are superficial rather than radical, and refer chiefly to the form of the case, and facilities for its accurate pointing. The linear bolometer is now made to expose to the radiant heat a vertical tape or wire of platinum, iron or carbon. This is usually about 10^{mm} long and only from $\frac{1}{1000}$ to $\frac{1}{100}^{mm}$ thick, but according to its special purpose it is made from 1^{mm} to $0{\cdot}04^{mm}$ wide. In the latter case it appears like the vertical strand of an ordinary reticule in the focus of a positive eye-piece attached to the case and is movable by a micrometer screw. It is in fact in appearance a micrometer thread, controlled in the usual way, but which is connected with the galvanometer and endowed with the power of feeling the radiations, visible or invisible, from any object to which it is directed. For very feeble sources of heat, such as those with which we are here concerned, the strip is made as much as a millimeter in width, and is not provided with a micrometer screw, but moves with the arm carrying it, and its positions are read by the divided circle of the spectrometer to 10″ (ten seconds of arc). It is this simple form of the instrument which has been used in the present investigation, and which is shown in Plate II. The bolometer is shown in position in the middle of the case where its central strip is accurately self-centered in the cylinder. For protection from air currents, since the obscure heat studied will be stopped by a glass cover, we must make use of the special device I have described, in the memoir just referred to, of successive chambers or drums separated by diaphragms with a common central aperture.

With these precautions, and with the special adjuncts before described, a bolometer with a strip $\frac{1}{25}^{\text{mm}}$ wide can be set by the invisible heat alone to within 10″ of arc, while in the ordinary use of the linear thermopile we are liable to errors of a considerable fraction of a degree. Even with a bolometer 1^{mm} wide, it will be subsequently seen, we can set to 1′ of arc. This refers only to the precision of pointing attainable; we will consider the sensitiveness of the instrument later in connection with the galvanometer.

Galvanometer.

It must be remembered that while the nominal sensitiveness of a galvanometer can be increased to any extent by increasing the astaticism of the needle (quite as nominal power can be multiplied to any extent on a telescope by altering lenses at the eye-piece), that the real or working capacity depends upon the ability to always obtain a like result under given conditions. Accordingly we have continued to devote great pains to extend our original conception, so as to make the galvanometer, as well as the bolometer, not merely an indicator of heat, but a real "meter," which shall distinctly answer the question "how much?" as to almost infinitely minute amounts of energy.

For the benefit of any physicists who may desire to repeat these experiments, we may observe that we have found the bolometer capable of almost unlimited delicacy of perception of heat, but that our chief trouble has arisen from the difficulty of constructing a galvanometer suitable to develop its full capacity for exact measurement. We have been unable to find among galvanometers ordinarily constructed one capable of indicating with precision changes in the amount of current of much less than $\frac{1}{1,000,000}$ of an Ampère. It was in the construction of a galvanometer designed to measure the heat in the spectrum of the moon, that we acquired the experience which we have utilized in the present researches.

A reflecting galvanometer of the form devised by Sir William Thomson has been used for the basis of our construction, and altered as follows. (For several of the changes described I am indebted for suggestions due to the great kindness of Sir William Thomson and Professor Rowland.) First, the short suspending fiber supplied by the makers has been replaced by one 33^{cm} in length, stretched and prepared with particular care. Next, since the effect of a given minute change of current is proportionable (other things being equal) to the magnetic moment, and to the minuteness with which the angular deflection of the needle can be read, we have reconstructed the mirror and needles as follows. For the magnets* soft sheet steel $\frac{1}{20}$ of a mm. thick is rolled up into minute hollow cylinders each about 8^{mm} long and about 1^{mm} diameter. These are hardened and made to take a permanent charge of nearly 900 Gaussian units. Ten of these are placed behind the back of the mirror and ten below, making twenty in all. The reflecting mirror is accurately concave, being specially worked for the purpose, $9{\cdot}5^{mm}$ in diameter, 1 meter radius of curvature, weighing 63 milligrams and platinized on the front face by the discharge *in vacuo* of platinum electrodes, through the process of Professor Wright† of Yale College. The stem which unites the upper and lower system of the magnets is a hair-like and hollow tube of glass, while it occurred to me to replace the aluminum vane of the ordinary instruments, by the wings of a dragon fly (*Libellula*), in which nature offers a model of lightness and rigidity quite inimitable by art.

The glass plate which encloses the front of the galvanometer has optically plane and parallel sides, and the screen, placed at 1 meter distance from the mirror, is a portion of a cylinder 1 meter in radius, divided into 500 divisions of 1^{mm} each. The optical arrangements for illuminating and forming an image of the wire form one of such precision that a motion of $\frac{1}{10}$ of one of these divisions can be distinctly noted. There is an independent provision by means of which the image of a second opaque and inverted scale can be viewed by the observer through a telescope, not as in the ordinary construction, directed on to a flat, attached to the needles, but in which the concave mirror, already described, becomes itself the mirror of a Herschelian telescope. Ordinarily the condition of astaticism of the needle is such that without any damping magnet, it will execute a single vibration in not less than 15 nor more than 30 seconds. Much greater sensitiveness can be given to it, of course, but without, as we have found, corresponding advantage.

For the purpose of forming an estimate of the sensitiveness of the instrument, it may be stated that, when making a

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* The design and construction of the hollow magnets is due to Mr. F. W. Very, of this Observatory.

† Professor Wright has had the goodness to platinize these delicate mirrors for us himself.

single vibration in 20 seconds a deflection of 1^{mm} division of the scale is given by a current of 0·000,000,000,5 Ampères through the coils of 20 ohms resistance; and, as we have just remarked, a tenth of one of these divisions can be discriminated. That this degree of sensitiveness is associated with a real, and not nominal, corresponding degree of accuracy, is shown by the fact that many series of accordant measurements have been made when the maximum deflection did not exceed three such divisions: and that similar measures have been made in the invisible spectrum given by ice melting in a dark room, when the maximum deflection observed was $1·6^{mm}$ and most deflections less than one millimeter. On the other hand, the exposure of the same bolometer to ordinary direct sunlight with only $\frac{1}{1000}$ of the current passing, i. e. with the galvanometer shunted 1,000 times, would drive the needle immediately, and with violence, off the scale.

Our experience has shown us that this galvanometer, in conjunction with such a bolometer as we have described, is capable of recording a disturbance of rather less than $\frac{1}{1000000000}$ part. To attain corresponding accuracy in gravity determinations we should need to have a balance capable of weighing a kilogram which would give at the same time an unequivocal deflection for a difference of one one-thousandth of a milligram in either pan. A deflection of 1^{mm} corresponds, in the case of such a bolometer as we have used in the lunar spectrum, or in that of melting ice, to a change of temperature in the bolometer strips considerably less than $\frac{1}{100000}$ of a degree Centigrade, and we have just seen that about $\frac{1}{10}$ of this can be shown. In other words, about one-millionth of a degree can be indicated by it, and a quantity less than one hundred thousandth of a degree not only indicated but measured. It will be obvious to the practiced observer, that this degree of accuracy will not be in reality reached, unless the bolometer strips are perfectly protected from all extraneous radiations and air currents, and especially unless the image is fixed upon the scale when the bolometer is not exposed to heat. This degree of precision we believe ourselves to have actually obtained.

Gratings.

Of the concave gratings we have three, of the very largest size. These magnificent instruments we owe not only to the skill, but to the special kindness, of Professor Rowland, who has been good enough to execute them for us of the very short focus and open ruling, necessary for our particular work.

Let us designate them as gratings No. 1, No. 2 and No. 3. The dimensions of grating No. 1 have been given in a prior memoir, but we repeat them here with some other data, for the reader's convenience. The limit of precision, imposed by the use of the bolometer, makes it superfluous to introduce any temperature correction, or to give the figures with more exactness than we here do.

NAME.	Grating No. 1	Grating No. 2	Grating No. 3
Radius of curvature	1626·^{mm}	1753·^{mm}	1627·^{mm}
Number of lines to mm	142·1	142·1	113·7
Height of ruled portion	102·^{mm}	80·^{mm}	75·^{mm}
Width of ruled portion	146·	132·	133·
Distance corresponding to 10,000 of Angström's units on the line of wave lengths, S_1S_2	231·0^{mm}	249·1^{mm}	185·0^{mm}

The ruled portion of each of these truly superb instruments occupies from 100 to 150 square centimeters. On their exquisite definition we need not enlarge, since sufficient of them are now in the hands of physicists to make our commendation superfluous.

We have already described the action of the grating. The essential feature, for our purpose, is that, under the stated conditions, we can in theory be absolutely sure of the wave-length of the *invisible* ray under examination by choosing it a multiple of the wave length of some *visible* line in the superposed spectrum which is coincident with slit S_2.

Thus, in the case of our illustration, we have supposed the sodium line to be used, since this is conspicuous in that of the sun and easily reproduced in that of the arc. The wave-length we are in search of, is always a times the wave-length of D_2 (a being some aliquot number). In practice we thus, for greater certainty, always form the image of some line in the visible spectrum on slit S_2, although, as already explained, its mere position on the line S_1 S_2 is, if the apparatus be in adjustment, a guarantee that none but the exact ray and its multiple comes under examination.

Lenses and Prisms.

The rock-salt lenses, L_1, L_2, are of different focal lengths for different occasions. For the extremely feeble heat we are considering we are using very clear and perfectly figured salt lenses of 75^{mm} aperture and 350^{mm} focus; this small ratio of aperture to focus in the lenses being required to economize the feeble heat as much as possible. The prism used with them is first set to minimum deviation on some visible line, and then automatically kept there for the invisible ray under consideration.

We owe these specimens of rock-salt to the particular kindness of Professor Hastings of Yale College, and their extremely exact surfaces to Mr. Brashear of Allegheny, the maker of the surfaces on which the Rowland gratings are ruled. On this portion of the apparatus alone very great labor has been expended.

We have procured through Mr. Brashear's skill, by means previously described, a rock-salt prism having a field filled with Fraunhofer lines and showing distinctly the nickel line between the D's. This is true when first polished, as it comes from the maker's hands; but owing to the deliquescent nature of the material, with the utmost care, the surfaces rapidly deteriorate. As it is necessary for the precision of these researches to determine the refracting angle of the prism, and also the indices of refraction of some of the principal lines in its visible and invisible spectrum with a high degree of accuracy, and as all these labors have to be repeated when the prism is re-polished, some idea of the work in this portion alone may be understood, when it is stated that the prism has been sent to the maker and entirely refigured, and its principal constants redetermined by us, no less than thirteen times in the past fourteen months, or since the first of January, 1885.*

We now give two examples of actual measurement of wave-lengths: the first, that in sunlight in a flint prism, which we have designated as No. 2; the second, in the rock-salt prism just mentioned.

First example of measurement. With flint glass prism.

(Extract from original record.)

Station, Allegheny.
Date, March 3d, 1886.
Temperature of apparatus = − 1°·8 Cent.
State of sky, clear overhead, cirrus clouds near the horizon.
Aperture of slit (S_1) = 2^{mm}.
Aperture of slit (S_2) = 1^{mm}.
Lenses of glass (non-achromatic) focal length = 800^{mm} for visible rays.
Grating, Rowland No. 1 (concave).
Prism, H. No. 2 (glass). Refracting angle = 62° 15′ 03″.
Spectrum thrown east.
Galvanometer No. 3, damping magnet at 40^{cm}.
Time of single vibration = 21 sec. (with current passing).
Bolometer No. 16 (aperture = 1^{mm}).
Reading on slit (before mounting prism), 0° 00′ 00″.
Reading on D_2 (through prism), 52° 52′ 40″.
Current of battery = 0·036 Ampères.†

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* For a full description of the constants of this prism, see this Journal, Dec., 1885.

† It must be understood that this is the *total* current of the battery. The differential current which passes through the galvanometer is of an altogether different order of magnitude, in this case probably not exceeding 0·00000001 Ampère.

Reader at circle, F. W. V.
Reader at galvanometer, S. P. L.

OBJECT = measurement of deviation of $\lambda = 4 \times \lambda D_2$ in the spectrum of the flint glass prism H. No. 2 with sunlight.

Galvanometer deflection with arms in line (from the combined effect of all the grating spectra falling on slit 2) a little over 300 divisions.

Prismatic deviation.	49° 00′	48° 58′	48° 56′	48° 54′	48° 52′	48° 50′
Galvanometer deflections. First series	11	10	11	18	19	12
	2	13	12	15	13	15
Mean deflections	6·5	11·5	11·5	16·5	16	13.5
Galvanometer deflections. Second series	13	21	26	32	25	20
	14	22	24	31	30	13
Mean deflections	13·5	21·5	25	31·5	27·5	16·5

Concluded maximum at 48° 54′.

Making the galvanometer deflections ordinates, and the prismatic deviations abscissæ, a smooth curve through the points of observation gives, in the first case, a maximum of 48° 54′. The image of the slit has a certain size, and so has the bolometer strip. The latter feels the heat before the center of strip and image coincides, and it is this point of the coincidence of centers which gives the maximum as denoted by the above figures.

We now make a second series, and though the two series follow each other at a brief interval on a day described as "clear," the values of the deflections in the second series on the same points indicate nearly twice the heat in the first. The change is chiefly due to the altered diathermancy of the apparently clear sky in the brief interval. It is one of the difficulties already signalized by the writer and by others,* and is to be eliminated only by repeated observation. The second series, however, gives the same deviation as the first, and hence we conclude (as far as this day's observation goes) that this is the index of refraction for the wave-length in question and for a certain flint prism. Such observations must generally be repeated on many days before a reliable result is reached; and in the case of the glass prism, which grows rapidly athermanous just beyond the limit of the solar spectrum, they are limited, by the nature of the substance, to little more than the wave-length in question.

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* See Crova, Comptes Rendus, vol. ci, p. 418, Aug. 10th, 1885.

We now consider as our second example a measurement at $5\times\lambda D_2$, where glass can hardly be used, and where its place is supplied with the rock-salt prism, and that of the sun by the arc.

Second example of measurement. With rock-salt prism.

(Extract from original record.)

Station, Allegheny.
Date, April 15th, 1886 (P. M.).
Wet bulb at $4^h\ 30^m$ (inside dark room artificially heated) = 21°·0 Cent.
Dry bulb at $4^h\ 30^m$ (inside dark room artificially heated) = 26°·4 Cent.
Aperture of slit $S_1 = 4^{mm}$.
Aperture of slit $S_2 = 1{\cdot}25$.
Prism used, Hastings No. 1 (rock-salt).
Lenses used, focus = 760^{mm} for visible rays.
Grating used, Rowland No. 2.
Galvanometer No. 3, damping magnet at 40^{cm}.
Time of single vibration = 17·5 sec. with current.
Bolometer No. 16 (aperture 1^{mm}).
Setting on slit = 0° 00′ 00″.
Setting on D_2 (spectrum thrown east) = 41°·03′ 00″.
Setting on D_2 (spectrum thrown west) = 319° 57′ 40″.
Current of battery = 0·037 Ampère.
Reader at circle, J. P.
Reader at galvanometer, F. W. V.
Arc managed by A.

OBJECT = determination with the great arc of the deviation in a rock-salt prism corresponding to a wave-length of $5\times\lambda D_2 = 2^{\mu}{\cdot}945$.

Spectrum thrown east.

Deviation.	39° 21′		39° 18′		39° 15′		39° 12′	
First series	1·3 1·3	1·3	3·3 3·4	3·4	5·5 5·4	5·5	2·3 3·4	2·9
Second series	−1·0 −0·8	−0·9	0·6 1·6	1·1	7·5 6·3	6·9	1·7 1·7	1·7

Spectrum thrown west.

Third series	1·0 0·4	0·7	2·1 2·7	2·4	4·1 3·9	4·0	0·2 −0·1	0·1
Fourth series	−0·1 0·2	0·1	2·3 2·4	2·4	3·4 3·6	3·5	−0·1 0·3	0·1

The sodium line of the fifth spectrum fell exactly upon the slit S_2 at the beginning and end of the observations.

From smooth curves the following positions were deduced for the maximum:

Spectrum east	39° 15′·7
Spectrum east	39 15 ·0
Spectrum west	39 16 ·0
Spectrum west	39 16 ·4
Mean =	39° 15′·8

The following measurements of wave-length with the grating have been carried on continuously from December, 1885, to April, 1886. As a rule each of the sixty-two determinations in the following table represents one or more day's labor, though in some cases two or more have been secured in the same day.

They have been taken under the following conditions:

(1.) In the case even of the very lowest wave-lengths in the feeblest heat, we have been able to use a linear bolometer of not more than 1^{mm} width.

(2.) About an equal number of observations were intended to have been taken with the prism placed so as to throw the spectrum east and west. In doing this a minute systematic error amounting at the greatest to less than 1′ of arc was found to be caused by flexure of the arm, due to the weight of the bolometer cable, and a correction for this has been applied. Otherwise the observations are given as originally made; and as the "probable error" here includes all the more or less systematic differences, due to the use of different gratings, and different positions of the apparatus, it may be considered to be in this case, a fair indication of the amount of error to be actually expected.

We do not know of any determination of the change produced in the refractive power of a rock-salt prism by varying temperature. A rough comparison of the deviations of Fraunhofer lines, incidentally measured in the progress of the work at different seasons, during which the temperature has varied nearly 30° Cent., together with the results of a single day's measures at temperatures differing by 17° Cent., have concurred in indicating a diminution in the deviations throughout the visible spectrum of about 11″ for a rise of temperature of 1° Cent.

We do not doubt that a temperature correction is also required for the invisible spectrum; but not having yet been able to satisfactorily determine any, we think it best to leave all the observations as they stand, uncorrected for temperature, and offer them under this reserve, now, with the intention of returning to them hereafter.

In the following table we repeat for convenience, the results of certain optical measures made on September 14th, 1885, by Mr. J. E. Keeler with the rock-salt prism, whose refracting angle was on that date 59° 57′ 54″, and which we have reduced to 60° by the formula given in this Journal for December, 1885. The wave-lengths are those due to Peirce's and Rowland's corrections of Ångström, with which we have been favored by the authors before their formal publication.

In the succeeding portion of the table, we have the results of measures made with the bolometer in the invisible spectrum. The first column gives the source of heat; the second, the wave-length selected for measurement; the third, the grating employed; the fourth, the refracting angle of the prism on the day of observation; the fifth, the temperature of the apparatus; the sixth, the observed deviation; the seventh, the mean deviation corrected for flexure error and reduced to a refracting angle of 60°; the eighth the resulting index of refraction for rock-salt.

Source of Heat.	Wave Length.	Grating.	Refracting Angle.	Temperature.	Observed Deviation.	Mean Deviation Reduced to 60°.	Index of Refraction.
Sun	0^{μ}·39687	------	59° 57′ 54″	24°	43° 14′ 44″	43° 17′ 15″	1·56833
	·48614	------	"	"	41 51 47	41 54 09	1·55323
	·51838	------	"	"	41 32 52	41 35 13	1·54975
	·58901	------	"	"	41 02 41	41 05 00	1·54418
	·58961	------	"	"	41 02 29	41 04 48	1·54414
	·65630	------	"	"	40 42 56	40 45 13	1·54051
	·75940	------	"	"	40 22 25	40 24 41	1·53670
Arc	$2\times\lambda D_2=$ 1·1780	No. 1	59 57 20	24	39 46 0	---------	
	---- ----	------	"	"	46 40	---------	
	---- ----	------	59 58 50	26	48 20	39 49 18 ±12″	1·5301±·0001
Arc	$3\times\lambda D_2=$ 1·7670	No. 1	59 57 20	24	39 31 0	---------	
	---- ----	------	"	"	32 0	---------	
	---- ----	------	59 58 50	26	32 30	39 34 06 ±12″	1·5272±·0001
Arc	$4\times\lambda D_2=$ 2·3560	No. 1	59 58 50	26	39 24 0	---------	
"	---- ----	------	"	-------	22 40	---------	
"	---- ----	------	59 59 34	−1·1	22 24	---------	
Sun	---- ----	------	"	0·6	24 06	---------	
"	---- ----	------	"	0·6	25 06	39 24 18 ±18″	1·5254±·0001

Source of Heat.	Wave Length.	Grating.	Refracting Angle.	Temperature.	Observed Deviation.	Mean Deviation Reduced to 60°.	Index of Refraction.
Arc	5 × λD_2= 2·9451	No. 1	59° 58′ 20″	19°	39° 14′ 42″	--------	
	--------	------	"	"	15 06	--------	
	--------	------	59 57 45	21·8	16 48	--------	
	--------	------	--------	"	16 30	--------	
	--------	------	--------	"	15 18	--------	
	--------	------	--------	"	17 42	--------	
	--------	------	--------	"	17 24	--------	
	--------	------	--------	"	15 36	--------	
	--------	------	--------	"	16 00	--------	
	--------	------	--------	23·8	16 18	--------	
	--------	------	--------	"	15 54	--------	
	--------	------	--------	"	15 48	--------	
	--------	No. 2	--------	26·4	16 30	--------	
	--------	------	--------	"	15 48	--------	
	--------	------	--------	"	15 12	--------	
	--------	------	--------	"	15 36	39° 18′ 12″ ±2″·4	1·5243±·0000
Arc	6 × λD_2= 3·5341	No. 1	59 58 20	14	39 04 00	--------	
	--------	------	59 57 45	16	06 48	--------	
	--------	------	--------	"	06 24	--------	
	--------	------	--------	15	08 54	--------	
	--------	------	--------	"	10 00	--------	
	--------	------	--------	"	9 30	--------	
	--------	------	--------	"	8 30	39 09 54 ±30″	1·5227±·0002
Arc	7 × λD_2= 4·1231	No. 1	59 57 45	15	39 02 18	--------	
	--------	------	--------	"	01 48	--------	
	--------	------	--------	"	00 30	--------	
	--------	------	--------	"	02 00	--------	
	--------	------	--------	23·8	01 36	--------	
	--------	------	--------	"	00 48	--------	
	--------	------	--------	"	01 42	--------	
	--------	------	--------	"	00 42	39 03 42 ±12″	1·5215±·0001
Arc	8 × λD_2= 4·7121	No. 1	59 57 45	15	38 51 18	--------	
	--------	------	--------	"	50 48	--------	
	--------	------	--------	"	52 12	--------	
	--------	------	--------	"	54 42	--------	
	--------	------	--------	"	54 42	--------	
	--------	------	--------	"	54 12	--------	
	--------	------	--------	"	57 36	--------	
	--------	------	--------	"	55 18	38 56 06 ±30″	1·5201±·0002
Arc	9 × λD_2= 5·3011	No. 1	59 57 45	15·4	38 45 12	--------	
	--------	------	--------	"	45 42	--------	
	--------	------	--------	"	47 12	--------	
	--------	------	--------	"	48 48	--------	
	--------	------	--------	"	47 18	38 48 06 ±30″	1·5186±·0002

In the following brief table we have summarized the results of all this labor. Our working method gave the index in terms of the wave-length, but since ordinarily the former is the known, and the latter the unknown quantity, we here give the mean probable error as finally corrected as a function of the latter.

Given Indices of Refraction in Rock-Salt Prism.	Wave-Lengths from Direct Observation, (*a*) by the eye. (*b*) by the bolometer.
1·5442	$\lambda D_2 = 0^{\mu}\cdot5890 \pm 0\cdot000$ (*a*)
1·5301	$2 \times \lambda D_2 = 1\cdot1780 \pm 0\cdot002$ (*b*)
1·5272	$3 \times \lambda D_2 = 1\cdot7670 \pm 0\cdot005$ “
1·5254	$4 \times \lambda D_2 = 2\cdot3560 \pm 0\cdot009$ “
1·5243	$5 \times \lambda D_2 = 2\cdot9451 \pm 0\cdot013$ “
1·5227	$6 \times \lambda D_2 = 3\cdot5341 \pm 0\cdot019$ “
1·5215	$7 \times \lambda D_2 = 4\cdot1231 \pm 0\cdot029$ “
1·5201	$8 \times \lambda D_2 = 4\cdot7121 \pm 0\cdot043$ “
1·5186	$9 \times \lambda D_2 = 5\cdot3011 \pm 0\cdot065$ “

In Plate IV, we have graphically constructed the relations between n and λ for the rock-salt prism, as far as the above wave-length of $5^{\mu}\cdot3011$ or $0\cdot0053^{\text{mm}}$. The ordinates are proportional to the indices of refraction given on the axis of Y, the abscissæ to the wave-lengths on the axis of X. The two vertical dotted lines carry the eye down to the corresponding portion of the spectrum, which is visible. Between these lines, lie the points of the visible spectrum observed on, and the dotted curves show the results of extrapolation by various formulæ.

The actual points settled by observation are certain multiples of the wave-length D_2 ($0\cdot0005890^{\text{mm}}$) and a small circle whose diameter equals a unit in the *third* decimal place of the scale of ordinates (indices) gives the position fixed by observation, while the distance from the center at which the smooth curve cuts the little circle furnishes a graphic presentation of its difference from observation. The labors of the past year, then, have enabled us to absolutely and directly measure the index of refraction of rays whose wave-lengths are greater than $0\cdot005^{\text{mm}}$, or more exactly, which reach 53011 of Ångström's scale, and to do so, with an error which is probably in most cases confined to the fourth decimal place of the index. As we shall see more clearly by Plate IV, the relation between n and λ has changed from that apparently complex one we see in the visible spectrum, so that n becomes almost a simple linear function of λ, and the results of extrapolation grow to a higher order of trustworthiness than when made from points in the visible spectrum alone.

It appears to us that no formula of dispersion with which we are acquainted* gives entirely correct results on extrapolation, but that among the best are Briot's and Wüllner's. We have computed the wave-lengths corresponding to indices of refraction from observed deviations in the visible spectrum according to these formulæ. The curve from Cauchy's formula we do not give, because (at least when not more than three terms are taken from observations in the visible part of the spectrum), its results are here of little value, since it declares all the radiations we are now actually dealing with, to be impossible of discrimination at all. Redtenbacher's formula we have also shown in a previous memoir to be scarcely worth further consideration. The graphically constructed values are obtained by applying the formula of Briot,

$\left(\frac{1}{n^2} = a + b\frac{n^2}{\lambda^2} + c\frac{n^4}{\lambda^4} + k\frac{\lambda^2}{n^2}\right)$.............to the four points:

A ($\lambda = 0^{\mu}{\cdot}7601$. $n = 1{\cdot}53670$)
D_2 ($\lambda = 0^{\mu}{\cdot}5889$. $n = 1{\cdot}54418$)
b_1 ($\lambda = 0^{\mu}{\cdot}5183$. $n = 1{\cdot}54975$)
H_1 ($\lambda = 0^{\mu}{\cdot}3968$. $n = 1{\cdot}56833$)

and the formula of Wüllner, $\left(n^2 - 1 = -P\lambda^2 + Q\frac{\lambda^4}{\lambda^2 - \lambda^2_m}\right)$, to the three points:

A ($\lambda = 0^{\mu}{\cdot}7601$. $n = 1{\cdot}53670$)
b_1 ($\lambda = 0^{\mu}{\cdot}5183$. $n = 1{\cdot}54975$)
H_1 ($\lambda = 0^{\mu}{\cdot}3968$. $n = 1{\cdot}56833$)

All these are in the visible spectrum, and from them the constants a, b, c, k, P, etc., are determined. With their aid we next enquire, by the formula, what wave-lengths correspond to certain given indices, and the resultant values in the infra-red are then plotted from these computations. It is, however, only just to observe that the wide departure from observation here shown is by no means to be wholly attributed to error in the formula, for minute errors of measurement, such as are always present even in the observations in the visible spectrum, are immensely exaggerated by extending the curve through extrapolation. Wüllner's formula, for instance, would give a line closely coincident with our curve in the infra-red if we took all our points for computation from that part of the spectrum. A similar remark may be made of Briot's equation, whose actual tracing, however, with the constants we obtain from the visible spectrum, shows that beyond a certain point, the curve which is

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* That proposed by Ketteler has come to the writer's knowledge too late for trial here.

its geometrical representation, from being concave to the axis of X, becomes convex, so that the relation between n and λ would, according to it, be represented by a sinuous line, and this is not so within the limits of these observations. Its fair agreement with observation then, within the limits of the visible spectrum and the upper part of the solar infra-red, are all that can be claimed for it.

Our conclusion is that all theories of dispersion known to us prove inadequate to predict the relation between wave-length and refraction.

The actual relation from direct investigation is here given for the first time from the observations of the past year, which it will be seen, thus confirm and greatly extend the results of 1882 and 1884. Their most salient feature is still perhaps that already noted, i. e. while the curvature, as far as we can follow it, grows less and less, at the last point at which we can view it the curve is not only all but sensibly a straight line, but one making a very definite angle with the axis of X. This obviously means that beyond this point n is nearly a linear function of λ or that the simple equation $n=a\lambda$ would very closely represent this portion of the curve. It means also that, as far as these observations extend, *we find scarcely any limit to the index of the ray which the prism can transmit* except from its own absorption.

I do not, it will be observed, undertake to advance without limit beyond observation, or to discuss what would happen with wave-lengths so great that the index became 0 or negative, as it would with an indefinite prolongation of the curve, if its direction remain unaltered. An intelligible physical meaning might perhaps be attached to these cases; but I here confine myself to the results of direct observation, and to the now established fact that the increase of the crowding together of the rays at the red end, which is so conspicuous a feature in the upper prismatic spectrum, has almost wholly ceased; and that the dispersion has become approximately uniform, the action of the prism here being assimilated to that of the diffraction grating itself.

I shall not venture to treat of the theoretical import of this, further than to remark that the ordinary interpretation of Cauchy's theory will apparently lead us to conclude that dispersion must sensibly cease at the point where the wave is so long that the size of the components of matter is negligible in comparison. In other theories also, there appears to be a point below which the index of refraction should never fall, and we might anticipate that the curve would accordingly tend to become parallel to the axis of X. Of course we cannot assert from observation that it will not finally do so, but within the very extended limits in which we have followed it, the contrary happens, and the curve presents an increasingly constant angle with that axis.

These results, in some material points, are in contradiction to what has usually hitherto been believed.[*]

Let me repeat that one consequence of the fact that the curve is approaching a straight line is that, unless there is some immediate change in its character, such as we have no right to expect, extrapolation considerably beyond the point to which we have measured will be comparatively easy and safe. I am aware of the danger attending all extrapolations, but I must insist upon the fact that the old ones, which we have falsified by experiment, rested on extremely limited regions of the curve, that, namely, for the visible region of the spectrum, in which the relation between n and λ is also wholly different; while those, on which we now briefly enter, depend upon far greater material for induction (about eight times that included in the visible spectrum), which we can also use under much more favorable conditions.

Since the curve still presents a slight convexity to the axis of abscissæ, unless its character changes in a way which we have no ground to expect, a tangent at any point will meet that axis sooner than the curve itself will. Accordingly if we now ask what wave-length corresponds to any point in the hitherto unexplored region, for instance, the maximum in the spectrum of boiling water whose index[†] for the rock-salt prism is 1·5145[‡] or that of melting ice whose index is 1·5048, we can answer as follows: First, this unknown wave-length is at any rate greater than $5^{\mu}\cdot 3$ since to this point we have investigated by direct measurement; second, since the tangent to our curve even at the point 5^{μ} meets the line corresponding to the index of the maximum heat in boiling water at over 7^{μ} and a line corresponding to the maximum ordinate in the spectrum of melting ice at over 10^{μ}, and since the curve without some change in its essential character cannot meet these save at still greater wave-lengths, it follows that the wave-length of the maximum of the spectrum from boiling water is probably at least $\cdot 0075^{\mathrm{mm}}$, and that of the maximum in the spectrum from melting ice is over $0\cdot 01^{\mathrm{mm}}$. In an article in the Comptes

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[*] I am very desirous that they should be verified by physicists, and I have therefore given particulars in some detail of my methods and apparatus here. I have requested the skillful artists (Mr. Wm. Grunow, mechanician to the U. S. Military Academy, West Point, N. Y., Mr. J. A. Brashear, Allegheny, Penn.) who have so successfully constructed this apparatus, to place at the command of physicists all or any details of it.

[†] Determined as described in this Journal for January, 1886, by means of the apparatus shown in Plate II.

[‡] See Plate III, this Journal for Jan., 1886.

Rendus of the Institute of France, January 18, 1886, and in preliminary memoirs, we deferred giving the actual values, but gave (explicitly as minimum values which we believed much within the truth) 5^{μ} to 6^{μ}. That our caution led us to understate the even then most probable value, may be seen from the statements just made, which are founded on still later observations.

As we proceed farther out, extrapolation becomes, of course more untrustworthy. We can only say that if the curve maintains its present inclination to the axis of X, the wave-lengths of the extreme radiations recognized in the rock-salt prism must indefinitely exceed $0{\cdot}03^{\mathrm{mm}}$.

We have shown that the various complex formulæ founded on theoretical considerations differ from observation; and as we have remarked, they have the minor objection also of being extremely difficult of application to practical uses, owing to the inordinately tedious numerical computations involved where many places are to be calculated.

Struck by the resemblance of the actual curve of observation as viewed in a large graphical construction, to a hyperbola, I was therefore led some years ago to use the equation of the hyperbola as an empirical one for interpolations in the infra-red without attaching any physical meaning to it. The further the investigation has been pushed in that part of the spectrum, the more exact the resemblance has become. That it is noticeable, will be seen on consulting Plate IV,* where the hyperbola does not appear as a distinct curve, because its variation from the smooth curve of observation cannot be recognized on this scale.

In obtaining this we have proceeded as follows: Having five disposable constants, we have taken five nearly equidistant points on the smooth curve of observation, remembering that if the axis of Y is not exactly asymptotic to the curve thus described, we are not necessarily to impute the difference to the equation chosen, since the condition that the curve of observation shall be rigorously asymptotic to this axis can in any case only be satisfied by infinite exactness of measurement.

It will be observed that my estimates of the extreme wave-lengths are in no way founded on the use of this hyperbola, and that I do not assert that it has any physical meaning.

I have elsewhere observed that while Herschel in 1840, Draper in 1842, Fizeau and Foucault in 1846, Lamansky in 1870, together with others since, had observed bands in the infra-red prior to 1881, yet that nothing was exactly known as to the

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* It should be mentioned that some of the observations on which the computations are founded have been added since this drawing was prepared for the engraver.

wave-lengths of these bands, even to those who discovered them. It is very likely that the (probably telluric) absorption band in the solar spectrum placed on the Allegheny chart (Comptes Rendus, Sept. 11, 1882) at $1^{\mu}\cdot 38$ had been recognized by more than one of the above mentioned observers, yet so little was known as to its actual position, even a few years since, that we find the elder Draper, in reviewing these former observations in 1881, and speaking with the authority of one who was himself a discoverer, expresses his doubt as to the possibility of any wave-length so great as $1^{\mu}\cdot 08$ having really been observed, and M. H. Becquerel (Annales de Chimie et de Physique, 1883, tome xxx, p. 33) gives the wave-length of the longest band known to him as $1^{\mu}\cdot 50$. These remarks will not be superfluous as an introduction to the following table, which presents a summary view of the advances made beyond the above-named point in the last five years.

Extreme lengths of visible and invisible etherial radiations and of sonorous waves.

Quality of radiation and means of recognition.	Wave-lengths in units of one millimeter.	Description.
Invisible ultra-violet radiations.	0·000185	Extreme rays of aluminum in the induction spark. Recorded by photography.
(Photography.)	0·000295	Extreme limit of solar spectrum at sea-level on best days, according to Cornu, recorded by photography.
Visible radiations.	0·00036	Limit of lavender light, visible to normal eyes.
(Eye.)	0·00081	Extreme limit of deep red light, visible to normal eyes.
Beginni'g of infra-red (Phosphorescence.)	0·0010	Supposed extreme possible limit of infra-red wave-lengths in 1881, according to J. W. Draper.
Photography, (Abney). Phosphorescence, (Becquerel).	0·0015	Wave-lengths assigned by H. Becquerel to lowest absorption band known to him in 1883.
(Bolometer.)	0·0027	Sensible limit of solar infra-red rays which penetrate our earth's atmosphere. Determined by the grating and bolometer, Allegheny, 1882.

Quality of radiation and means of recognition.	Wave-lengths in units of one millimeter.	Description.
Invisible infra-red radiations from terrestrial sources. (Bolometer).	0·0053	Limit of absolute measurement of wave lengths corresponding to a given index of refraction in the case of a rock-salt prism. Determined by the Rowland grating and bolometer, Allegheny, 1886.
	0·0075	Approximate position of the maximum ordinate in the heat spectrum from a lamp-blacked surface at the temperature of boiling water (100.°). Allegheny, 1886.
	0·011	Approximate position of the maximum ordinate in the "heat" spectrum from a lamp-blacked surface at the temperature of melting ice (0°). Allegheny, 1886.
	0·030	Approximate estimate of the minimum value assignable to the longest wave recognizable by the bolometer in any heat from a rock-salt prism.
Sonorous Vibrations. (Ear.)	14·0	Length of shortest sound wave corresponding to highest musical note perceptible by human ear. (Approximately 48,000 s. v. per sec.) Savart.

Broadly speaking, we have learned through the present measures with certainty of wave-lengths greater than 0·005$^{\text{mm}}$, and have grounds for estimating that we have recognized radiations whose wave-length exceeds 0·03$^{\text{mm}}$, so that while we have directly measured to nearly 8 times the wave-length known to Newton, we have probable indication of wave-lengths far greater, and the gulf between the shortest vibration of sound, and the longest known vibration of the ether, is now in some measure bridged over.

In closing this memoir, I must add that the very considerable special expenses, which have been needed to carry on such a research, have been met by the generosity of a citizen of Pittsburgh, who in this case, as in others, has been content to promote a useful end, and declines publicity for his name.

I cannot too gratefully acknowledge my constant obligation to the aid of Mr. F. W. Very and Mr. J. A. Keeler, of this Observatory, who have labored with me throughout this long work. In the prolonged numerical and other computations rendered necessary, I have been aided by Professor Hodgkins, of Washngton, and by Mr. James Page of this Observatory.

Allegheny Observatory, May 31, 1886.

Art. X.—*On the chemical composition of Herderite and Beryl, with note on the precipitation of aluminum and separation of beryllium and aluminum;* by S. L. Penfield and D. N. Harper.

1. *Composition of Herderite.*

The rare material for carrying on the present investigation of herderite was given to us by Mr. L. Stadtmüller and Professor George J. Brush. The crystals were carefully picked by hand and freed as far as possible from all foreign matter. They were then crushed and sifted and suspended in the Thoulet solution; only the material whose specific gravity was greater than 2·95 was used for analysis. By this means there was separated from the hand-picked crystals a little questionable material, which was used in making a sort of preliminary analysis, and we were able to obtain over five grams of very pure material. Before making the separation with the Thoulet solution we carefully took the specific gravity of some of the purest crystals by taking the specific gravity of the solution in which they were suspended without floating or sinking. This we found to be from 3·012 to 3·006, the heaviest being the specific gravity of a very clear transparent crystal, while the more opaque and cracked crystals were a trifle lighter. The mineral is so much heavier than the quartz and feldspar to which the crystals were attached, that we feel very confident of the purity of the material which we analyzed.

The analysis was made after we had had considerable experience in the determination of beryllium and had made some experiments in determining it in presence of phosphoric acid. The method which we adopted gave good satisfaction, and we give it here somewhat in detail. The mineral was dissolved in nitric acid, the solution concentrated to a small volume, sulphuric acid was added, and the gypsum crystals after being collected by filtering through a rubber funnel were ignited and weighed as $CaSO_4$. The filtrate was concentrated in a platinum dish and gently ignited to drive off all hydrofluoric acid and the excess of sulphuric acid. The residue was dissolved in hydrochloric acid, a basic acetate precipitation of a part of the beryllium and phosphoric acid was made in the cold with ammonium acetate, and a little calcium precipitated from the acetic acid filtrate by ammonium oxalate, which was ignited and weighed as CaO. The beryllium in the filtrate from calcium oxalate was precipitated as a phosphate by means of ammonia, filtered, and the phosphoric acid in the filtrate precipitated with magnesia mixture. The two precipitates containing the beryllium as phosphate (the basic acetate precipitate contained the bulk of the beryllium) were ignited in the same crucible and fused with sodium carbonate. The fused material was soaked out in water, phosphoric acid obtained in the solution by the usual method, while the insoluble beryllium oxide was dissolved in hydrochloric acid, precipitated with ammonia, weighed, and the trace of P_2O_5 contained in it separated with ammonium molybdate. The P_2O_5 and bases in analysis III, on which we place the greatest confidence, were separated and determined in the above manner.

Other determinations are given to show the accuracy of the method. The CaO in II was all obtained in the filtrate from the basic acetate precipitation and was not partially precipitated as gypsum. The BeO in the same analysis was tested for Al_2O_3, but not more than a questionable trace could be detected. The P_2O_5 in I was from a direct determination with ammonium molybdate, but a very slight mechanical loss was incurred. The fluorine was determined in III by driving off the silicon fluoride and titrating the hydrofluosilicic acid by means of a standard alkali.* After making the determinations, fresh U-tubes were connected with the apparatus and the aspiration carried on for several hours, but no more silicon fluoride was driven off. As our alkali had just been standardized by means of sodium carbonate and test experiments on fluor spar, we feel very confident that the fluorine determination is correct. The water determinations are somewhat surprising. Mackintosh† made no tests for water, and considered the mineral to be an anhydrous phosphate with fluorine. Winkler‡ made no determination of fluorine and obtained no satisfactory tests for that element by etching glass. He obtained a loss by ignition, however, of 6·59 per cent in the Stoneham mineral by strong ignition, which he regards as water. Genth§ obtained 6·04 per cent of fluorine by direct determination, and 0·61 per cent of water by heating the mineral with lead oxide to bright redness. Mackintosh‖ obtained good tests for fluorine by etching and found a loss of 6·03 per cent by strong ignition. He proved conclusively that fluorine was given off by strong ignition, and concludes that it is replaced in part at least by oxygen. We are scarcely willing to believe that such a reaction would take place on heating an anhydrous phosphate containing fluorine. Our first water determination was made by weighing out the mineral in a boat, placing it in a combustion tube containing a layer of dry sodium carbonate, igniting the tube to full redness and collecting the water in a weighed chloride of calcium tube. We obtained 0·69 per cent; afterward the mineral was dissolved, and analysis II completed

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* Am. Chem. Journal, i, 27.

† This Journal, III, xxvii, 135.

‡ Neues Jahrbuch für Mineralogie, 1884, ii, 134.

§ Proc. Amer. Phil. Society, xxi, 1884, 694.

‖ This Journal, III, xxviii, 401.

from the same material. After almost completing our analysis and finding only 5·27 per cent of fluorine we tried the following experiments. A little herderite powder was placed in a hard glass tube, sealed at one end and ignited; at first only a slight film of water condensed in the cold part of the tube; by strong ignition over the blast lamp, however, there was a sudden evolution of hydrofluoric acid, which etched the glass very perceptibly near the mineral and deposited a film of silica and very acid water, as marked as in an ordinary reaction for fluorine in a closed tube with acid sulphate of potash. In our experience we have never seen any hydrous fluoride which gives off such strongly acid water and such a marked fluorine reaction. Some of the powdered mineral was placed in a closed glass tube, covered with a layer of dry sodium carbonate and strongly ignited; neutral water was given off and condensed as a ring, which indicated more than a trace of water. The water was obtained in the following way. About two grams of calcite were ignited over the blast lamp till a constant weight was obtained. The mineral was then weighed into the same crucible, the lime was slaked with water, the contents of the crucible were carefully dried and then ignited till constant weight was obtained, the water being calculated from the loss of weight. The slaking of the lime makes an intimate mixture of the mineral with the lime, and a preliminary experiment proved to us that only neutral water was driven off. In I there was a slight mechanical loss in slaking the lime, which caused the water determination to be too high, the P_2O_5 too low. In III the water was obtained from a larger quantity of mineral. No sublimate was formed on the cover of the crucible by the volatilization of any fluoride. The analyses were made on air-dry powder which lost 0·10 per cent by drying for one hour at 100° C. The beryllium precipitates were always of a light cream color after ignition, indicating that not more than a minute trace of iron was present.

The following quantities of mineral were used in making the analyses: I. ·4552 grams; II. 1·0029; III. P_2O_5 and bases ·7336, F ·9692, H_2O 1·1612.

	I.	II.	III.	Ratio.			Calculated.
P_2O_5	43·47	- --	43·74	·308		1·	43·83
BeO	----	15·28	15·51	·620		2·01	15·44
CaO	----	33·61	33·67	·601		1·95	34·57
F	----	----	5·27÷38	·138	·343	1·11	5·86
H_2O	4·37 ?	----	3·70	·205			2·77
			101·89				102·47
O equivalent of F.......			2.22				2·47
			99·67				100·00

The ratio of $P_2O_5 : BeO : CaO : (F_2+H_2O) = 1:2:2:1$ nearly. The high temperature at which the water is driven off indicates that it is not water of crystallization, but is very firmly united in the mineral as hydroxyl, every H_2O representing two hydroxyl groups, and the OH being probably isomorphous with F. The ratio of $F:OH$ is nearly $1:1$, or more nearly $3:4$ in our analysis. In the calculated analysis we have used the ratio $F:OH=1:1$, but recognize that it is probably simply a case of isomorphism. The composition of herderite is, therefore, an isomorphous mixture of $CaBeFPO_4$ with $CaBe(OH)PO_4$, which may be written $CaBe(FOH)PO_4$, or a salt of phosphoric acid, two of whose hydrogen atoms have been replaced by a bivalent element, and the third likewise by a bivalent element whose other free affinity has been satisfied by a fluorine atom or hydroxyl. This is the same composition as that proposed by Mackintosh, except that he regarded the mineral as simply the fluorine compound and did not detect the water. Chemically herderite is closely related to the three minerals—wagnerite, triplite and triploidite, whose compositions are respectively Mg_2FPO_4, $(FeMn)_2FPO_4$ and $(FeMn)_2(OH)PO_4$. These three minerals offer the best illustration we have of the isomorphism of F and OH, and we feel that we have in herderite another strong proof of the correctness of this interesting relation. In crystallization the minerals vary, herderite being orthorhombic, triplite questionable, and wagnerite and triploidite monoclinic. The latter two have, like herderite, a prismatic angle of nearly 120°.

2. *Analysis of beryl.*

In 1884 one of us* published a series of analyses which showed that alkalies are present in beryl sometimes to quite a large extent, and that water is always given off by ignition. At the time the analyses were made the author had had little experience in the determination and separation of beryllium and used the ammonium carbonate method, which seemed to him to be the most accurate. Our experience has taught us that the method used in the manner described in the above mentioned article gives too low results for beryllium, and the analyses are only of value as showing to what extent alkalies and water are present in beryl. Since the publication of the article it has always been the author's wish to make a series of experiments on the separation of aluminum and beryllium and renew the investigation.

We have considered it best not to make a long series of

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* S. L. Penfield. This Journal, III, xxviii, 25.

beryl analyses, but to select some very pure beryl and make an analysis of it as carefully as possible. The analysis was made according to the method described at the end of this article, and we feel assured from our experience that the results of the analysis represent the composition of the mineral very closely. The beryl which we selected for analysis was a very pure transparent aqua marine from Stoneham, Maine, furnished to us by Mr. George F. Kunz of New York. The mineral was crushed and ground in a steel mortar and the fine powder boiled in dilute hydrochloric acid, washed and dried at 100° C. Duplicate analyses were made by both of us, so that we might obtain a very fair average.

Specific gravity taken on a chemical balance, 2·706.

		Ratio.		
SiO_2	65·54	1·092		6·
Al_2O_3	17·75	·172	·173	0·95
Fe_2O_3	·21	·001		
FeO	·38	·005	·558	3·06
BeO	13·73	·541		
CaO	·06	·001		
Na_2O	·71	·011		
Li_2O	trace			
H_2O	2·01	·112		0·61
	100·39			

The ratio of $SiO_2 : Al_2O_3 : RO : H_2O = 6 : 1 : 3 : ·5$ nearly. The ratio of the first three is in the proportion required by the usually accepted formula for beryl. This conclusion was also arrived at by Baker* in a recent analysis made according to the same method which we used. As regards the alkalies, we have as yet no proof that they replace the beryllium, but that is probably the case. Analyses of beryls very rich in alkalies would best settle this question. The water is very constant, about two per cent, in all beryls which have come to our notice, with one exception—Aduntschilon, Siberia†—and must be in some way very firmly united in the molecule, as it is only given off by very strong ignition. As can be seen by our ratio, there is about one-half a molecule present. Beryls which show a higher percentage of water may, and in some cases which have come under our observation do, contain mechanical inclusions of water. Regarding the water as essential, we would have to add $\frac{1}{2}H_2O$ to the ordinary accepted formula of beryl, or write it $H_2Be_6Al_4Si_{12}O_{37}$. The theoretical composition according to the above formula is

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* American Chem. Journal, vii, 175.

† This Journal, III, xxviii, 29.

SiO_2	65·81
Al_2O_3	18·83
BeO	13·71
H_2O	1·65
	100.00

We can add also the alkali determinations in the following European beryls. The alkalies were determined by Smith's fusion method and calculated as sodium, although they all contained some lithia. Limoges, France, 0·73 per cent; Hühnerkobel near Bodenmais, Bavaria, 1·20 per cent; Habachthal, Tyrol, 2·26 per cent.

3. *On the precipitation and washing of aluminum.*

Before making the above investigations we tried a few experiments in the precipitation and handling of aluminum precipitates which may be of interest to some of our readers. A standard solution of aluminum chloride was first made containing ·1002 grams Al_2O_3 and 1 c.c. pure concentrated HCl in every 50 c.c. which were used in our experiments. The precipitation of the alumina was in all cases made in a volume of about 300 c.c. by neutralizing the solution with ammonia till the odor of ammonia could be distinctly obtained from the hot solution; the beaker was then placed upon a lamp stand and the solution brought to boiling, which was not continued more than one minute. The precipitates were in all cases washed without a pump, but suction tubes 7 inches long were attached to the funnels which cause a gentle suction, and if the filter papers are carefully fitted to the funnels very materially hasten the filtration.

The following facts were observed: that precipitates which were made in solutions containing large quantities of acid, either hydrochloric or nitric, filtered as well or better than those from solutions containing little ammonia salts, but on washing with boiling water the precipitates from solutions containing large quantities of ammonia salts became very sticky, washed slowly, so that it was almost impossible to free them from the last traces of ammonium chloride, and that very perceptible quantities of alumina settled out from the filtrates and washings on adding a few drops of ammonia and allowing the beaker to stand in a warm place. Further, that all of the alumina which ran through did so during the washing. The precipitates after they had become slimy and sticky seemed either to be quite soluble in the hot water or else got into such a condition that they readily passed through the pores of the paper and stopped them up, thus hindering the filtration. To make a successful precipitation and washing of alumina it is quite essential not to have very much ammonia salts present and even with the greatest care it is found that if the filtrates and washings are set away in a warm place, slight precipitates will almost invariably settle out. The above holds good for solutions containing ammonium chloride and nitrate. The fact that alumina passed through the filter only during the washing suggested to us that if we could wash the precipitate with a saline solution which would be completely volatile and do no harm to the precipitate we might avoid the passage of the alumina through the filter and it might also hinder the packing of the precipitate. Ammonium nitrate suggested itself to us as a salt which would be volatile on ignition and do no harm, and our experiments with it have been very satisfactory. The following strength of NH_4NO_3 has been used in all of our experiments—2 c.c. of pure concentrated HNO_3 neutralized with ammonia and diluted to 100 c.c. with water; this strength has proved so satisfactory that we have tried no other. Using this hot saline wash instead of hot water the precipitation can be made in solutions containing large or small quantities of ammonium salts and no very great care is needed in adding the ammonia. According to our experience, the precipitates from solutions containing a goodly quantity of ammonia salts, resulting we will say from 4 to 8 c.c. of pure concentrated hydrochloric or nitric acid, filter and wash better than precipitates from solutions containing less saline matter. After having made a large number of precipitations we can say that only in one or two cases have we found a trace of alumina in either the filtrate or washings, and that unless the precipitate becomes too dry and packs too firmly upon the sides of the funnel, the washing goes on as well at the end as at the beginning, and there is no difficulty in washing the precipitate free from all traces of chlorine.

Where large quantities of sodium or other fixed salts are to be removed and a second precipitation of the alumina is required, we recommend that the first precipitate after washing be dissolved in nitric instead of hydrochloric acid, then very little washing is enough to free the second precipitate from the last traces of chlorine and fixed salts.

Why ammonium nitrate acts in this way wé are not able to state. It may be something on the same principle that sediment deposits much faster in saline than in fresh water. We are convinced that any one who has to handle troublesome alumina precipitates will find the above method of washing of great advantage.

4. *On the separation of aluminum and beryllium.*

Various experiments convinced us that the following methods are not satisfactory: pPrecipitation of the alumina as basic acetate, some beryllium being also precipitated; precipitation of the alumina with barium carbonate; solution of the beryllium in a boiling solution of ammonium chloride; by long boiling of a solution of ammonium chloride the solution becomes slightly acid and according to our own experience some alumina is dissolved, while Genth* found that the beryllium was not completely dissolved. Solution of the beryllium in and precipitation of the alumina with ammonium carbonate gives unreliable results, and the method, when carried out as described by one of us in making a series of beryl analyses,† gave too low results for beryllium.

We have made a large number of separations by dissolving the mixed chlorides in the least possible excess of caustic soda, diluting the solution largely and precipitating the beryllium by boiling. This method has recently been proposed by Genth‡ as the most reliable of the known methods, and Baker§ used it successfully in his analysis of beryl. Before using the method in our own work we made a series of experiments to determine its accuracy and to find out the best conditions for making the separation. A standard solution of beryllium chloride was made from purified K_2BeF_4 containing ·1107 grams BeO in every 50 c.c. Our standard solution of aluminum chloride contained ·1002 grams Al_2O_3 in every 50 c.c. Neither of the solutions contained any alkali and not more than traces of sulphuric acid.

The method was as follows: 50 c.c. of each solution were measured into a platinum dish and evaporated to dryness, the chlorides were dissolved in the least possible quantity of water, and a rather strong solution of pure soda, made from metallic sodium, was cautiously added till the precipitate which at first formed was completely dissolved. The contents of the dish were then rinsed with cold water into a beaker containing about 800 c.c. of boiling water and the contents of the beaker boiled for one hour, replacing from time to time the water which evaporated. The beryllium separates out as a granular precipitate which is easy to filter and wash. After acidifying and concentrating the filtrate the alumina was precipitated with ammonia. Our experience has taught us that the best results are obtained by dissolving the dried chlorides in the least possible quantity of water and using as little soda as possible for dissolving the aluminum and beryllium.

Below we have given in tabulated form the results of our experiments.

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* Proc. Amer. Phil. Society, xxi, 694, 1884.

† Loc. cit.

‡ Loc. cit.

§ American Chem. Journal, vii, 175.

	Weight of Al_2O_3.	Weight of BeO.
	·1041	·1093
	·1057	·1080
		·1096
	·1045	·1099
		·1107
	·1032	·1093
	·1037	·1093
	·1031	·1083
Average	·1040	·1093
Standard	·1002	·1107

The precipitates were in all cases ignited for a long time to full redness over a ring burner. It will be seen that the BeO is quite constant and the average only a little below the standard. The Al_2O_3 is in all cases too high. If the quantity of mixed beryllium and aluminum oxides be determined in any compound, and then the BeO separated according to the above method and the Al_2O_3 determined by difference, the results will be very nearly correct. The determinations of Al_2O_3 and BeO in beryl given earlier in this article were made in this way.

To account for the excess of Al_2O_3 we thought that perhaps appreciable quantities of silica were dissolved from the glass by boiling the alkaline solutions of the mixed oxides for one hour. We therefore in every case dissolved the oxides in hydrochloric acid and deducted from their weight a slight quantity of insoluble matter amounting to about ·0010 grams in the Al_2O_3 and ·0004 grams in the BeO. The excess of Al_2O_3 must, therefore, have come from some other cause than silica dissolved from the glass. The alkaline solutions are so dilute that the glass is very little acted on, and determinations made in a platinum dish convinced us that the separation can be made just as well in beakers. We have concluded that the beryllium is not completely precipitated from a solution in soda by boiling and that it is not possible to wash out all of the soda from the precipitate. The following experiments on the determination of BeO in beryl will show this. The first column gives the weight of BeO obtained by boiling the soda solution, the second the same oxide dissolved in hydrochloric acid, reprecipitated with ammonia and ignited.

·1476	·1440
·1464	·1422
·1330	·1300
·4270	·4162

The total BeO in these experiments weighed ·4270 on first precipitation, ·4162 on second, a loss of ·0108. Calculating by proportion the loss which would result from ·1107 grams BeO the quantity used in our first experiments we find

$$·4270 : ·1107 = ·0108 : x. \quad x = ·0027$$

that is, in the quantity of BeO which we used in making our experiments, the BeO was too heavy by about ·0027 grams, representing probably some soda compound which could not be removed by washing. The excess in the Al_2O_3 is due to the BeO which was not precipitated by boiling. If we take the sum of the Al_2O_3 and BeO in the average of our determinations ·2133 and deduct from it ·0027 we have ·2106 against ·2109, the sum of Al_2O_3 and BeO in our standard. The following determinations made from our standard solutions, the boiling of the soda solutions being done in platinum, confirm us in this. First weight of BeO ·1087 after solution and reprecipitation ·1068, weight of Al_2O_3 ·1041. ·1068 + ·1041 = ·2109, the weight of mixed oxides in our standard. We conclude therefore that the separation is not as perfect as our results would indicate. The error is however very constant, the amount of BeO which is not precipitated being almost exactly equal to the amount of soda which it seems impossible to remove from the precipitate by washing.

When phosphoric acid is present alumina may be separated from beryllium by boiling the solution of the mixed chlorides with barium hydroxide. The alumina goes readily into solution while the precipitate containing the barium phosphate and beryllium is easy to filter and wash. After dissolving the precipitate and separating the barium with sulphuric acid, a beryllium phosphate can be precipitated with ammonia. After weighing this the P_2O_5 may be determined by means of ammonium molybdate and the BeO by difference or the precipitate may be fused with sodium carbonate and the fusion soaked out with water which gives almost a complete separation of phosphoric acid from beryllium. If phosphoric acid is also to be determined it must be borne in mind that very perceptible quantities of it will be found in the barium sulphate precipitate.

We have also observed that when Al_2O_3 is ignited over a ring burner till a constant weight is obtained, then over a blast lamp there is a slight loss, amounting in the quantities which we have used in making the above experiments to about ·0010 grams. What this loss represents we are not able to say. Usually in practical work this error can not be avoided, because it is necessary to dissolve the ignited Al_2O_3 to test for traces of SiO_2 or iron, and it is almost impossible to dissolve Al_2O_3 which has been strongly ignited over a blast lamp. The same is true for ignited BeO. After strong ignition over a ring burner there is still a loss of about ·0013 in the quantities which we used, by igniting for five minutes over a blast lamp. This may be done however, as the ignited BeO is readily soluble in hydrochloric acid.

In closing we wish to express our thanks to Messrs. Geo. J. Brush, L. Stadtmüller and Geo. F. Kunz for the rare material which they kindly furnished for carrying out this investigation.

Mineralogical Laboratory, Sheffield Scientific School, May 28th, 1886.

ART. XI.—*Communications from the U. S. Geological Survey, Division of the Rocky Mountains.* VIII. *On Ptilolite, a new Mineral;* by WHITMAN CROSS *and* L. G. EAKINS.*

THE mineral described beyond occurs in cavities of a more or less vesicular augite-andesite which is found in fragments at a certain geological horizon in the conglomerate beds of Green and Table Mountains, Jefferson County, Colorado. The formation to which this conglomerate belongs is of Tertiary age and will be described in the report upon the geology of the Denver coal-basin now in preparation by the U. S. Geological Survey. For the present article it is sufficient to say that the conglomerate in question is chiefly composed of worn pebbles and bowlders of andesitic rocks, embracing various types. The rock containing the new mineral has been found at several different places upon the mountain slopes, at approximately the same horizon in the series, and its fragments are not so worn and rounded as are those of other rocks in the conglomerate. Various structural modifications of this andesite have been found, ranging from the compact massive rock to that which is decidedly vesicular.

The massive rock is dull ashen-gray in color, exhibiting a few dark augite prisms and tabular feldspar crystals as the only macroscopic constituents. A microscopical examination shows the rock to consist of a network of small plagioclase microlites with irregular augite grains in very small quantity between them. In spots there seems to be a development of quartz in clusters of minute grains. No glassy base was seen, but certain yellowish globulitic masses are apparently devitrification products. Porphyritic crystals of augite, biotite and plagioclase are comparatively rare. Chemical analysis of the massive rock gave the following result:

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* Read before the Colorado Scientific Society, May, 1886.

SiO_2	59·26
Al_2O_3	23·63
Fe_2O_3	·30
FeO	·57
CaO	5·93
MgO	·31
K_2O	4·78
Na_2O	4·94
H_2O	·74
	100·46

Analyst, L. G. Eakins.

The various porous or amygdaloidal fragments found evidently represent material from different positions in the original rock-mass, and according to the former position of each specimen there is a certain development of minerals in the vesicles or pores. A reddish-gray, finely cellular rock contains in some cavities creamy, banded opal, upon which a decided play of reddish color was noticed in certain spots. Chalcedony and quartz fill many cavities completely. Another rock specimen, in which the pores are all round and small, exhibits no minerals in its cavities. A third specimen is very porous, the pores being irregular though never greatly distorted. More than half of these cavities contain a banded deposit of opal and chalcedony, the banding having in all a parallel direction. A few pores are filled by clear chalcedony. All cavities not entirely filled in this manner show a crust of small, clear heulandite crystals of tabular form, with minute white globulitic masses of unknown character scattered over and between them. A still more porous rock in which the cavities are irregular shows traces only of the creamy opaline deposit, while heulandite and white globules of the unknown substance form a distinct crust. As a still more recent formation there appear in the pores of this rock small tufts of a white mineral. These are very delicate and could not be procured in sufficient quantity for chemical examination. The resemblance to mesolite, as it occurs in the basalt of Table Mountain, was so marked that for a time the identity of the two substances seemed possible, but these tufts belong to the new mineral, found more abundantly in other specimens.

On the north slope of Green Mountain there are fragments of this augite-andesite in some of which the white mineral in tufts is specially well developed. The rock is light reddish-gray and very vesicular, the pores being drawn out cylindrically in a certain direction. Many of these pores have been completely filled by a solid mass of chalcedony and quartz, the latter occupying the center. In other cavities there is merely a thin coating of pale bluish chalcedony, and upon this is deposited the above mentioned white mineral in most delicate tufts and spongy masses composed of short hair-like needles, loosely grouped together. These needles when examined under the microscope are found to be colorless, transparent prisms, the average diameter of which is less than 0·001^{mm}. The terminations of unbroken prisms are square, indicating the probable presence of a basal plane, parallel to which there are transverse fissures, as of cleavage. The extinction of the stouter prisms in polarized light is parallel to the prismatic axis, but the multitude of smaller ones are so delicate that they do not affect polarized light perceptibly.

In removing the mineral from the cavities, for chemical analysis, a small amount of chalcedony from the underlying coating, which scales off readily, was unavoidably mixed with the fine hairs. A separation was effected by throwing the unpowdered material into water and stirring, the spongy aggregates resolving readily into a cloud of minute white spicules which remained suspended while the solid particles of chalcedony with attached needles sank. After standing a few moments the supernatant liquid was poured off, this still containing in suspension the greater portion of the needles, which did not completely settle for several hours. Separation of the needles from other substances was thus made very complete and more than 0·5 gram of pure material secured for analysis. The result, with derived ratio, is as follows (L. G. Eakins):

SiO_2	70·35	÷ 60	= 1·1725	or	10·06	or 10
Al_2O_3	11·90	÷ 102	= 0·1166		1·00	1
CaO	3·87	÷ 56	= 0·0691	1116	0·96	1
K_2O	2·83	÷ 94	= 0·0301			
Na_2O	0·77	÷ 62	= 0·0124			
H_2O	10·18	÷ 18	= 0·5655		4·86	5
	99·90					

Special care was taken with the water determination of the above analysis. The mineral began to lose water at a very low temperature and even on drying in the air bath at 100° C. there was a noticeable loss; the amount thus lost, however, was found to be regained upon exposure to the air, and before the analysis was made the material was allowed to remain loosely covered for several days.

The loss of water, beginning at 100° C., continued steadily until at a temperature between 300° and 350° C. all the water was expelled, and continued heating at full redness occasioned no further loss. No line of demarkation could be detected at which the loss temporarily ceased, to begin again at a higher temperature, and thus no ground would seem to exist for considering any definite portion of this water basic, although a high temperature is necessary for its total expulsion.

Heated before the blowpipe a tuft of the mineral shrinks considerably and fuses to clear glass. Hydrochloric acid, even boiling, has little or no action, but by strong sulphuric acid it is gradually decomposed. Of course in a mineral of this description a determination of hardness is impossible and one of specific gravity would be too inaccurate to be of any value.

We propose as the name for this mineral, *Ptilolite*, derived from *πτίλον*, *down*, in reference to the light, downy nature of its aggregates.

Referring to the molecular ratio derived from the analysis, it is seen that the empirical formula for this mineral is $RO, Al_2O_3, 10SiO_2+5H_2O$, R representing Ca, K_2 and Na_2. The substance belongs among the alumino-silicates of which no previously described hydrate contains so high a percentage of silica. Perhaps the nearest allied hydrous mineral is stilbite, the composition of which may be expressed by the formula $H_4CaAl_2Si_6O_8, +4H_2O$.

While the structural formulæ for the complexer silicates are as yet hypothetical, it is of interest to note the place assumed by ptilolite in the scheme for the classification of the alumino-silicates adopted by Tschermak* and others. By the combination of the hydrous oxide $H_2Al_2O_4$ with two molecules of metasilicic acid, H_2SiO_3, through the elimination of $2H_2O$, there results a simple alumino-silicic acid with the empirical formula $H_2Al_2Si_2O_8$. By combining the same hydroxide with 4, 6, 8, 10, etc., molecules of H_2SiO_3 there results a series of alumino-silicic acids, the following anhydrous salts of which are known:

$Na_2Al_2Si_2O_8$ in sodalite,
$K_2Al_2Si_4O_{12}$ as leucite,
$K_2Al_2Si_6O_{16}$ as orthoclase,
$Li_2Al_2Si_8O_{20}$ as petalite.

Other series are obtained by starting with other hydroxides of alumina.

Petalite stands alone in the above series as the representative of its type, and members with higher contents in silica are yet unknown. Now the zeolites are in many cases simply hydrates of the above or closely allied salts, although the water may be in part basic. No hydrate of petalite or of any corresponding salt is known, but ptilolite is found to be the hydrate of $RAl_2Si_{10}O_{24}$ which will be seen to be the next member in the above series, following petalite.

If such a classification of alumino-silicates be adopted, ptilolite must be considered as the first member of a new group of

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* G. Tschermak, Lehrbuch der Mineralogie, 2te Aufl., 244, 438, 490.

hydrous minerals, and as R is composed of Ca, K_2 and Na_2 we can assume the possible existence of the pure lime, potash and soda compounds:

$$CaAl_2Si_{10}O_{24}+5H_2O$$
$$K_2Al_2Si_{10}O_{24}+5H_2O$$
$$Na_2Al_2Si_{10}O_{24}+5H_2O$$

The theoretical composition of an isomorphous mixture of these three compounds, in the ratio derived from the analysis of ptilolite, is given below in comparison with the analysis. The molecular weight of the mixed RO molecule was calculated to be 66·92.

	Calculated.	Found.	Difference.
SiO_2	69·86	70·35	+ 0·49
Al_2O_3	11·87	11·90	+ 0·03
CaO	4·04	3·87	— 0·17
K_2O	2·95	2·83	- 0·12
Na_2O	0·80	0·77	— 0·03
H_2O	10·48	10·18	- 0·30
	100·00	99·90	

The rare mineral milarite, although possessing a ratio RO : Al_2O_3=3 : 1, may yet be compared with ptilolite on account of its exceedingly high percentage in silica. Its formula is $HKCa_2Al_2Si_{12}O_{30}$, requiring 72·66 per cent SiO_2.

ART. XII.—*Notes on the Peridotite of Elliot County, Kentucky*; by J. S. DILLER.

SEVERAL years ago Professor A. R. Crandall discovered two dikes of an interesting eruptive rock in eastern Kentucky, about seven miles southwest of Willard. The position of these dikes is well shown upon Professor Crandall's geological map of Elliot County.

A preliminary examination of the rock under the microscope revealed the fact that it belongs to the peridotites. These rocks are considered by most petrographers as eruptive, but there are others who regard them as of doubtful origin. One of the latest writers on petrography* divides rocks into two great classes: (1) those resulting from the accumulation of material transported from lower to higher levels (Anogene), and (2) those resulting from the accumulation of material transported from higher to lower levels (Katogene). The first group includes rocks of eruptive origin, while the second con-

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* Elemente der Lithologie von Dr. Ernst Kalkowsky. 1886.

tains those derived from sedimentation. It is in the latter group that Kalkowsky places the peridotites. They nearly always occur intimately associated with highly altered rocks in regions of great disturbance, so that their relations cannot be readily determined. In eastern Kentucky, however, they are found with nearly horizontal unaltered sandstones and shales of the Carboniferous series and present such a promising opportunity for completely demonstrating the origin of peridotite that a more thorough examination has been undertaken.

The peridotite is a compact dark greenish rock with a specific gravity of 2·781. In it are embedded numerous grains of yellowish olivine uniformly distributed throughout the mass. Rarely it is fine-granular and dense like many dark colored basalts, but generally the grains of which it is composed are medium-sized. Occasionally the olivine grains wholly disappear and the deep green serpentine pervades the whole mass. Besides olivine and serpentine, which together form nearly seventy-five per cent of the rock, there are prominent grains of pyrope and ilmenite with a few scales of biotite.

The following table, showing the mineralogical composition of the peridotite, is based directly upon estimates made under the microscope of the areal distribution of the various minerals in the freshest portion of the sections taken from the locality where the peridotite is least altered.

Primary minerals.		Secondary minerals.	
Olivine ----	40 per cent.	Serpentine---	30·7 per cent.
Pyrope ----	8 “	Dolomite----	14 “
Biotite ----	1 “	Magnetite---	2 “
Enstatite --	1 “	Octahedrite -	1·1 “
Ilmenite ---	2·2 “		
Apatite----	*trace.*		

It is not claimed that this table represents with a high degree of accuracy the composition of the rock, but it closely approximates the real proportions in the sections studied. The table clearly indicates that originally at least eighty per cent of the peridotite was olivine, and that ultimately it will be nearly all serpentine, or perhaps in some places dolomite, with a small proportion of magnetite, ilmenite, pyrope and octahedrite.

The olivine generally occurs in the form of irregular grains held in the network of serpentine and other secondary products, but rarely, however, it is bounded by well defined crystallographic planes, a feature which is somewhat unusual for the olivine in peridotites. The crystals are short prisms terminated by brachydomes like those so commonly seen in basaltic lavas.

Enstatite plays so small a part among the minerals of this rock that it cannot be considered an essential constituent. It occurs in the form of irregular corroded grains with clouded borders and is distributed throughout the mass with approximate uniformity.

Next to the olivine, pyrope is the most important constituent of the rock. It occurs in the form of spherical or elliptical grains varying from one to more than a dozen millimeters in diameter. They are found abundantly along the line of the dike in the soil resulting from its disintegration. The small clear deep red grains have a specific gravity of 3·673 and are locally regarded as rubies of problematical value. The most interesting feature of the pyrope is prominent under the microscope, where it is seen to be surrounded by a border of radial fibres exactly analogous to those described by Schrauf* as Kelyphite and later critically examined by A. von Lasaulx.† In this case the border is composed of several essentially different substances which are always present although varying much in proportions. First of these may be mentioned a dark powder of magnetite which is frequently so abundant upon the outer edge of the border as to render it opaque. The inner substance of the ring is of a grayish or reddish brown color and generally fibrous in structure, perpendicular to the periphery of the garnet. The fibres have occasionally very strong absorption in the direction of the longer axis and have nearly or quite parallel extinction, indicating that the mineral is biotite. This conclusion is completely demonstrated by a border in part of which the uniaxial, negative, strongly dichroic folia of biotite may be clearly discerned. The biotite extends far into the fissures of the garnet and evidently results from its alteration. Associated with it are small triangular and quadratic sections of a yellowish brown isotropic mineral, which in all probability is picotite. Lasaulx clearly demonstrated the presence of pyroxene and amphibole, in the so-called Kelyphite. Becke‡ and Kalkowsky§ pointed out the picotite but so far as I am aware the presence of biotite in this connection is here noted for the first time.

The ilmenite is readily distinguished from the magnetite even under the microscope in reflected light by the brilliant coaly luster of portions of its pitted surface. It occurs in large grains and not in the form of spongy particles like the magnetite. Under the microscope the ilmenite is frequently seen surrounded, penetrated, and even completely replaced, by a mixed group of yellowish and black grains, resulting from its alteration. The black opaque grains are magnetite, but the

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* "Ueber die Umrindungen von Granat." Sitzungsberichte der Niederrhein. Gessell. zu Bonn. 1882, July 3.

† "Beiträge zur Kenntniss des Associations Kreises der Magnesiansilicate," Zeitschrift fur Krystallographie, 1882, vi, 321–388.

‡ Tschermak's Mineralog. und Petrographische Mittheilungen, iv, pp. 189, 285.

§ Elemente der Lithologie, p. 238.

yellowish ones are not as readily determined. They have a high index of refraction and are generally spherical, but occasionally their peripheries are straight and sharply defined, indicating crystallographic form. Such grains usually possess a higher degree of diaphaneity, and the sections are either triangular, square or diamond-shaped. The latter are most strongly doubly refracting, and extinction takes place parallel to the longest diagonal. No trace of cleavage could be discovered, but the facts enumerated render it highly probable that the mineral is octahedrite.

The relation of the peridotite to the Carboniferous sandstones and shales is of paramount importance in determining its age and origin. Only two reasonable hypotheses suggest themselves to my mind: (1) the peridotite may be older than the Carboniferous strata and formed on the floor of the sea a peak about which the horizontal strata were deposited; (2) the peridotite may have been erupted through the Carboniferous strata.

If the first hypothesis be correct we should expect to find the adjacent sandstone composed largely of detritus derived from the peridotite and to exhibit no evidence of contact metamorphism. On the other hand, if the second hypothesis be true there would not necessarily be a correspondence in the composition of the neighboring rocks and under favorable circumstances the sedimentary deposits would be metamorphosed near their contact with the eruptive. Chemical analyses 6 and 4 in the following table are of the adjacent sandstone and peridotite. The dissimilarity of the two rocks, both in chemical and in mineralogical composition, is so prominent as to at once dispel the thought that they are genetically connected. Although the exact contact of the two rocks was not exposed, hardened shale was found near the peridotite under such circumstances that its induration is certainly attributable to the influence of the eruptive mass. But this is not the strongest evidence, for the peridotite itself includes many fragments of shale which were picked up on its way to the surface. The contact metamorphism has resulted generally in the development of a micaceous mineral and the production from the shale of a rock such as has been designated spilosite. On the other hand, the peridotite itself has experienced endomorphic influences which resulted in the development to a very limited degree of a sphærolitic structure similar to that of the varioles in variolite.

The chemical analyses given in the following table were made with great care by T. M. Chatard, in the U. S. Geological Survey laboratory at Washington. The specific gravities were determined by the writer with a pycnometer in the case of the olivine, pyrope and ilmenite; for the others, Westphal's specific gravity balance was used. Analysis 5 is of a fragment of syenite found upon the border of the peridotite and supposed either to have been brought up from a great depth by the peridotite or else to have reached the surface by an independent eruption of syenite. A fragment of granulitic rock was also included in the peridotite, and that the latter is a truly eruptive rock which traverses many thousand feet of Paleozoic strata to reach the surface is a matter which does not admit of reasonable doubt.

	1. Olivine.	2. Pyrope.	3. Ilmenite.	4. Peridotite.	5. Syenite.	6. Calcareous S. S. near dike.	7. Fine grained fissile S. S. near dike.	8. Indurated shale near dike.	9. Fragment of slate included in peridotite.
Water at 110° (H_2O)	0·14	0·17	0·20	8·92	0·51	0·85	1·94		1·40
Water at red heat (H_2O)	0·66					2·32	5·17	8·78	9·00
Carbonic acid (Co_2)				6·66		6·29		0·55	0·88
Silica (SiO_2)	40·05	41·32	0·76	29·81	60·56	60.78	60·25	41·32	35·53
Titanic oxide (TiO_2)	0·07	0·16	49·32	2·20	1·19	0·03	0·23	0·48	0·95
Phosphoric acid (P_2O_5)	0·04	none	trace	0·35	0·30	0·09	0·10	0·08	0·08
Chromic acid (Cr_2O_3)	0·24	0·91	0·74	0·43				trace	
Alumina (Al_2O_3)	0·39	21·21	2·84	2·01	16·19	10·54	23·18	20·71	18·23
Ferric oxide (Fe_2O_3)	2·36	4·21	9·13	5·16	5·19	3·27	1·53	2·59	2·46
Ferrous oxide (FeO)	7·14	7·93	27·81	4·35	2·41		3·42	5·46	4·81
Manganous oxide (MnO)	0·20	0·34	0·20	0·23	0·36	0·10	0·10	0·17	0·13
Nickel oxide (NiO)	CoO = trace			0·05					
Lime (CaO)	1·16	4·94	0·23	7·69	2·09	10·15	0·51	9·91	21·17
Magnesia (MgO)	48·68	19·32	8·68	32·41	1·30	1·59	3·52	1·91	2·01
Potash (K_2O)	0·21	}	}	0·20	4·82	2·36	3·17	0·88	1·08
Soda (Na_2O)	0·08	0·07	0·19	0·11	4·78	1·41	0·39	7·19	2·53
Sulphur (S)				none					
Sulphurous acid (SO_2)				0·28					
Total	99·42	100·58	100·10	100·86	99·70	99·78	100·51	100·03	100·26
Specific gravity	3·377	3·673	4·453	2·781	2·633				2·489

U. S. Geol. Survey Office, Washington, D. C., March 29, 1886.

ART. XIII.—*Temperature Observations at the Lake Superior Copper Mines*;[*] by H. A. WHEELER.

THE copper mines of Keweenaw Point, Lake Superior, have attained such depth, as the result of the rapid prosecution of successful mining, that some of them are now among the deepest mines in this country. They therefore present an ex-

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[*] Presented before the St. Louis Academy of Sciences.

cellent opportunity for obtaining data as to the rate of thermal increase with descent into the earth. While the usual thermic gradient is between 50 to 55 feet for an increase in temperature of 1° F., exceptional gradients, both much higher as well as lower than this, have been obtained in certain localities. It was to add the evidence of this region in respect to this phenomenon, which is of economic as well as geological importance, that the writer made the following observations in some of the deeper mines of this now quite old mining district.

Keweenaw Point is a tapering peninsula that boldly extends in a general northeasterly direction out into the middle of Lake Superior, from its southern shore, for a distance of some 70 miles. It essentially consists of a series of parallel belts of fragmental and plutonic rocks that abut against sandstone, of supposed Potsdam age, on the eastern side, while they are conformably overlaid by sandstones and shales of Lower Silurian age on the western side. The plutonic rocks consist of amygdaloidal and compact melaphyres and diabase, while the intercalated fragmental rocks comprise numerous belts of a red conglomerate, the pebbles of which consist largely of quartz porphyry. These conformable belts have a dip of about 55° with a nearly northerly strike at the southern end, and gradually become flatter, and veer around until, at the extremity of the Point, at their northern end, the dip is only 20° and the strike easterly. The fractures incident to such a bending of the formation has resulted in fissures, in which some of the older mines are located, that are filled with zeolitic and other mineral matter and often are richly charged with copper.

Most of the mines are in either the melaphyre or conglomerate belts, in which the copper occurs disseminated in grains and masses in the native condition. The whole area is more or less thickly overlaid with glacial drift which in some cases is over 100 feet thick. The temperature observations were made during a rapid trip and the depths noted were taken from the mines, maps and other data obtained on the premises. Special care was taken to avoid modifying conditions at the observing stations, such as draughts, water, working places, etc., while duplicate readings were made of the thermometer. While the results obtained can scarcely claim to be more than close approximations, and are liable to be modified by more accurate and extended observations, they clearly show that the thermic gradient in this region is one of the lowest that has ever been noted; and the variations in the different mine seems to indicate the cause for this very low rate. The results of the observations are given in the following table:

Mine.	Thermal increase in feet for 1 degree Farenheit.	Vertical depth of mine in feet.	Distance between rating stations in feet.	Highest temperature of mine (Farenheit).	Character of "Lode."
Atlantic	99·5	907·	796·	51·6°	Melaphyre.
Central	101·	1950·	1860·	61·	Fissure vein.
Conglomerate	95·	617.	527·	48·3	Quartz prophyry Conglomerate.
Osceola	76·5	996·	860·	54·5	Melaphyre.
Tamarack	(110·7)	2240·	2104·	62·	Quartz prophyry Conglomerate.
Quincy	122·	1931·	1820·	58·5	Melaphyre.
Average	100·8*				

Of these observations, those at the *Atlantic* mine were made under very favorable circumstances and this particular rate of practically 100 feet to 1°, was closely checked by other determinations made on intermediate levels. In finding the rate for this mine, as in all other cases, as great a distance as possible was obtained between the two rating stations, while the upper station was always taken so far below the surface as to be beyond the influence of solar heat. The mine is about 2 miles south of Portage Lake, which is a narrow, long arm of Lake Superior.

The *Conglomerate* mine is about 36 miles northeast of the Atlantic mine, as measured along the formation, and like the Atlantic at the southern end, is at the other extreme of the series of mines examined, the others being between these two. It is in a belt of conglomerate, and is 3 miles distant from the shore of Lake Superior.

The *Central* mine is on a narrow fissure vein and is about 2½ miles distant from the Lake Superior shore line.

The *Osceola* mine is nearly 5 miles from the western shore line of Lake Superior and 4 miles from that of Torch Lake on the east side, the latter being a land-locked arm of the main lake. The rate determined on for this is the average of five different, closely agreeing rates, established between different levels of the mine. The observations made in this and the Tamarack mine were kindly volunteered by Mr. Frank Klepetko, the mining engineer of the company.

The *Tamarack* mine, unfortunately, did not furnish stations that could be regarded as reliable, as they were too close to active mining operations, and my notes show that the effect of the presence of miners, with their lights, blasting and rock-drills (worked by compressed air) give very erroneous results, especially the rock-drills with their ice-cold exhaust. So while I give the results of this mine, they are not to be accepted as satisfactory; this mine is 4 miles from Lake Superior.

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* With the "Tamarack" rate omitted, the average thermic gradient is 99· feet to the degree.

The *Quincy* mine is less than a mile from Portage Lake; in fact some of the workings on the vein extend nearly to the lake-side, while the melaphyre belt that the mine works crosses the lake. The mine workings, though now very much below the bottom of the lake, are quite free from water, the little they have being mostly of surface origin.

It is to this fact of the proximity of the mines to the cold waters of Lake Superior, that I wish to draw the reader's attention. For so far as I have been able to gather similar data, I have not found another instance where such very low thermic gradients have been observed, with the single exception of the Dukinfield Coal Pit, near Manchester, England, where a gradient of 90 feet to the degree is recorded. As no details were given with this, it is impossible to say whether this is the normal gradient for that region, or whether modifying influences, like an excessive influx of water, or other causes, may have made this simply a local rate. While the average rate of these copper mines is most exceptionally low and noteworthy, having quite possibly the lowest thermic gradient on record, the variations among the different mines is quite striking. In accounting for it, it should be stated that there is no reason to suspect that the observations of any one mine (with the exception of the Tamarack) are any less trustworthy than another. Nor does the nature of the rock in which the mine is worked seem to offer an explanation, for while three quite different classes of "lodes" are presented, the greatest variations occur in those whose characters are identical, to wit: the Atlantic, Osceola and Quincy, which are all in melaphyre. Though each of these mines is on a different belt of melaphyre, the general character of the entire formation is quite similar and alike, or a series of conformable, parallel belts of alternating conglomerates, melaphyres and diabase. The mines are quite similar in respect to freedom from water, all being comparatively dry mines, considering their extensive character, and what little water they have to contend with is quite generally of surface origin. In the mines mentioned there is at present no evidence of active chemical changes or reactions observable to cause this differentiation, while the general system of mining with rock-drills is carried on in all of them.

But when we consider their relation to one another as regards their proximity to Lake Superior, we are at once impressed by the close relationship between this distance and the thermic gradient; the mines nearest to the lake shore have the lowest gradient, while those farthest away have the higher or more rapid rate. When we consider the magnitude of Lake Superior and remember that only its surface waters change in temperature, as the great body of its deep waters remain constantly at the temperature of maximum density or 38·8° F.; and when we recall the excellent conducting power of water as regards heat, the influence of this great enveloping body of cold water can be at once appreciated. And it is primarily to it acting as a great cold blanket, that the writer attributes the general coolness of the rocks in this region, and secondarily in accounting for the local variations in the thermic gradient of the different mines. The nearer the mines are to this great cooling influence, the lower the thermic gradient will be found to be, while the farther one goes away the less will its influence be felt, until, should we pass entirely beyond such influence, we should probably get the very general and usual gradient of 50 to 55 feet. That such is the case seems to be indicated by the observations cited, and this is the theory offered by the writer. None of the mines mentioned are so distant from the cold body of lake water but that, notwithstanding the much smaller efficiency of rock-formations as heat conductors, they still show the effect of its strong influence. While the Osceola mine, with nearly 5 miles intervening between it and the main lake, shows that this thickness of rock-mass moderates very appreciably the refrigerating action of the lake it also indicates that, perhaps at a distance of 7 or 8 miles from the lake, such a thickness of rock-mass would render its effect inappreciable, and we should again have the normal gradient.

ART. XIV.—*An Application of the Copper Reduction Test to the Quantitative Determination of Arsenic;* by HENRY CARMICHAEL, Ph.D.

ONE milligram of arsenious oxide added to strong chlorhydric acid and digested at the boiling temperature with a clean polished piece of copper having a surface of forty square millimeters imparts to the copper a grayish tint without fully extinguishing the red color of that metal. The color darkens rapidly if a larger quantity of arsenious oxide is supplied, and if the copper is removed as soon as it has assumed a steel gray tint, it will be found that a milligram and a quarter of the oxide has been removed from solution. The transition from reddish gray to steel gray is so marked that the experimenter can readily match a specimen which has been selected as the standard of color.

As the arsenic compounds react more slowly and with less certainty, they should always be reduced to the -ous equivalent by means of sulphurous oxide before the trial is made. Using a standard square of copper as an indicator, the writer has been led to the adoption of a method which is believed to be, for the estimation of small quantities of arsenic, quicker, simpler, easier, more delicate, and, in the hands of toxicologists, less exposed to fallacy than any other.

A smooth, polished sheet of pure copper, not thicker than $0{\cdot}05^{\mathrm{mm}}$, is selected. As the commercial article is usually varnished, it must be cleaned with alcohol or otherwise. A neglect of this precaution is indicated by the irregularity of the arsenical deposit. The copper is cut into pieces $20\times21^{\mathrm{mm}}$. A strip one mm. wide is cut nearly across the longer side of each, and bent at a right angle to the general surface. These are the normal squares, and the bent strips are the handles by which they are manipulated. In applying the method, if the arsenic is possibly present in the substance under examination as an arsenic compound, it is digested with strong sulphuric acid, the solution reduced to a small volume, and after the conversion of the arsenic into arsenious oxide, strong chlorhydric acid is added. If the substance can only contain arsenic in the arsenious form, it is reduced to a small volume if liquid and strongly acidulated with HCl.

The acidulated solution is brought into a small porcelain capsule and a square of copper introduced. The capsule is placed over a small flame, and the square moved back and forth until it has acquired the tint of the standard chosen. The copper is removed, carefully washed and dried. The strength of acid is maintained by occasional additions, and squares are made to succeed one another until there is no further discoloration. The last square is usually lighter than the normal. Multiply the number of squares by the volume of standard arsenious solution which is necessary in coloring equally a single square, and subtract an amount which it is shown by trial the last square has required less than a normal square, and the total amount is given. By altering the concentration, the acidity, or the temperature, the rate of deposition is readily controlled. Two examples will illustrate the method.

(*a*.) A square of wall paper two inches on a side was placed in a capsule and drenched with strong HCl. A small flame was brought under capsule and squares of copper were successively colored to the standard until the exhaustion of the arsenic was marked by the lighter color of a surface long exposed to the acid liquid. The last was matched by a square which was known to have withdrawn $0{\cdot}13^{\mathrm{mgrm}}$ and the other five by a square which had withdrawn $0{\cdot}23^{\mathrm{mgrm}}$. The total amount, therefore, to the square yard of paper was $414{\cdot}7^{\mathrm{mgrm}}$. of arsenious oxide. The analysis, which consumed but a few minutes, was qualitative as well as quantitative. It may be of interest to state that the paper was "warranted strictly free from arsenic."

(*b.*) A human stomach sent for analysis was, after the usual physical examination, quartered. The part taken in the search for inorganic poisons was cut into small pieces and the organic matter destroyed with HCl and $KClO_3$ as usual. Through the filtered solution, which had been partially evaporated, SO_2 was passed and the excess removed. H_2S was passed through the warm solution for twelve hours. The precipitate was thrown on a small filter, and after thorough washing was drenched with NH_4HO. The filtrate was evaporated in small capsule, twice moistened with concentrated HNO at a steam heat, then moistened with fuming sulphuric acid and heated over direct flame until the unoxidized sulphur had run into a single globule and the organic matter had been charred. A little warm water was added, a few bubbles of SO_2 passed through the solution, and the excess removed. Concentrated HCl was added and normal squares successively coated. The total amount of arsenic in the stomach was computed to have been $2{\cdot}76^{\mathrm{mgrm}}$.

For verification one square was cut into narrow strips and pushed into a hard glass tube of the size of a quill. One end of the tube had previously been drawn down to a diameter of one mm. and the opposite end, after the introduction of the copper, was sealed with a mouth blowpipe. The bottle-shaped tube thus formed was placed in an air-bath for the expulsion of moisture and the bulb then raised to redness over a small flame. A white cloud formed and condensed in the neck. The sublimate was easily vaporized and driven from point to point. Under the microscope the coating appeared as an aggregation of sharply defined, highly refracting, regular octahedrons. The tube was sealed for future reference. The neck of a second tube, prepared in the same manner, was broken off and the arsenious oxide converted into the sulphide in a current of H_2S. The total exhibit then consisted of:

(1.) A steel gray film on copper which did not rub bright.

(2.) Highly refractive, regular octahedrons produced by the oxidation of said film and by sublimation, and which were easily vaporized, reforming as octahedrons.

(3.) A bright yellow substance formed by the action of H_2S upon the octahedral sublimate.

Confirmatory tests might easily have been applied, but the writer, having taken the customary precautions in testing purity of chemicals and utensils, considered the proof of arsenic preexisting in the material submitted for examination as abundant, and is of the opinion that such proof would, in similar cases, be only weakened and obscured by the employment of Marsh's or other familiar tests.

When the above method was first under trial, and it was not known how much the deposition of the steel gray film was influenced by foreign substances, the course of procedure was as follows:

The arsenious liquid under examination was placed in a burette and fed from this into the capsule containing hot chlorhydric acid and a copper square. After the exhaustion of the arsenic by the successive introduction of squares, the burette was filled with a standard solution of As_2O_3 (1 : 10,000), and this solution fed into the same liquid until the same number of squares were covered. The amount of arsenious oxide was then read directly from the burette. Theoretically superior, the results hardly excel in accuracy the results of the preceding method, while the time and care required are greater.

As a matter of curiosity it may be stated that a copper square one mm. on a side is capable of disclosing and estimating ·0000025 grm. arsenious oxide, a quantity four hundred times less than that necessary for turning the beam of the ordinary chemical balance.

The above quantitative method is commended for trial as being in the hands of experts free from fallacy; requiring few chemicals and utensils; not interfering with the search for other organic poisons and not interfered with by ordinary impurities, and as intelligible to the ordinary juryman, notwithstanding the quibbles of counsel.

Brunswick, Me., April 19, 1886.

ART. XV.—*On the Crystallization of Gold;* by EDWARD S. DANA.

THE attention of the writer has been directed recently to some specimens of crystallized native gold offering several points of interest and novelty. The crystallization of the native metals, gold, silver and copper, is a subject of more than usual difficulty, and for our knowledge in this direction we are largely indebted to the excellent work of Rose.* More recently vom Rath has made an important contribution in regard to the complex crystallized plates and thread-like forms of gold; Helmhacker† has described the interesting gold crystals from Sysertsk;‡ while v. Jeremejew,§ Lewis,‖ Fletcher¶ and Werner** have added to the list of observed forms.

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* Pogg. Ann., xxiii, 196, 1831; Reise nach dem Ural, i, 198, 1837, *et al.*

† Zeitsch Kryst., i, 1, 1877. ‡ Tschermak's Mineral. Mittheilungen, 1877, 1.

§ Verh. Min. Ges. St. Petersburg, II, v, 402, 1870.

‖ Phil. Mag., v, iii, 456, 1877. ¶ Ibid., ix, 1880. ** Jahrb. Min., i, 1, 1881

1. *Gold from Oregon.*

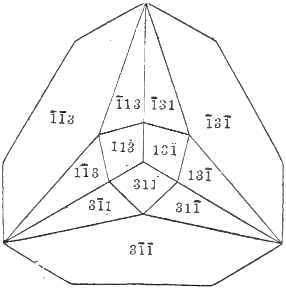
The delicate crystalline threads and arborescent forms of the gold from the White Bull mine in Oregon have long been a prominent ornament of collections, especially in America, but, so far as the writer is informed, no attempt has been made to describe them. A brief sentence is devoted to the subject in his Text-Book of Mineralogy, but the statement there is only partially correct.

The beauty and delicacy of these forms are perhaps unrivaled in the species, but to decipher them crystallographically does not seem at first to be especially easy. If examined superficially the threads appear to be made up of acute rhombohedral forms, closely crowded upon each other. The terminal crystal, which is in many cases much the largest of the series, usually shows also the presence of a six-sided pyramid at the apex, a form often only faintly indicated in the other crystals. In rare cases, where this terminal crystal is unusually well developed, close examination reveals also the presence of three other minute planes forming an obtuse termination to the hexagonal pyramid. The position of these planes at once suggests an explanation of the form, and a few measurements show that this explanation is the correct one. The planes observed are all those of the tetragonal trisoctahedron 3-3 (311), common in the species, and the peculiar appearance and apparent rhombohedral symmetry are due to the fact that the crystals are uniformly elongated in the direction of the octahedral or trigonal axis.

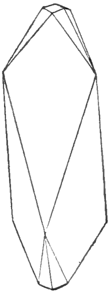
This is then simply a case of pseudo-symmetry, analogous to that by which a regular octahedron may be transformed into a rhombohedron with prominent basal plane, or into a simple acute rhombohedron if these two planes are suppressed; or again, to that in which a rhombic dodecahedron becomes a hexagonal prism terminated by rhombohedral planes; or, still again, like that which turns the trisoctahedron 2-2 (211) into a combination of an obtuse rhombohedron, a scalenohedron and a hexagonal prism. These are cases that have been long recognized. The case now described is remarkable for the regularity of the resulting forms and the way in which they are combined. This tendency in nature to thus imitate the symmetry of one system by the development of crystals belonging to another system, is in part explained by the fact that the planes whether referred to the one system or the other, have in either case rational symbols. Thus if we place a cube with its trigonal axis vertical, and regard it as the fundamental rhombohedron with a rhombohedral angle of 90°, the planes of the trisoctahedron 3-3 group themselves as follows (figs. 1, 2 and 3).

The planes 113, 311, 131, with the three opposite, form an obtuse rhombohedron with the symbol $\frac{2}{5}$-R ($20\bar{2}5$) and having a terminal angle (supplement) of 50° 29′. The six adjoining planes, $1\bar{1}3$, $3\bar{1}1$, $31\bar{1}$, $13\bar{1}$, $\bar{1}31$, $\bar{1}13$, with their opposites, form a hexagonal pyramid of the second series, with the symbol $\frac{4}{3}$-2 ($22\bar{4}3$); the terminal angle is here 50° 29′ and the basal angle 62° 58′. The six remaining planes of the twenty-four, namely $\bar{1}\bar{1}3$, $3\bar{1}\bar{1}$, $\bar{1}3\bar{1}$, and those opposite, form an acute rhombohedron with a symbol $4R$ ($40\bar{4}1$), and a terminal angle of 117° 2′.

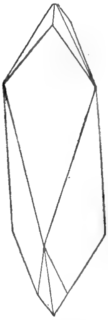
1.



2.



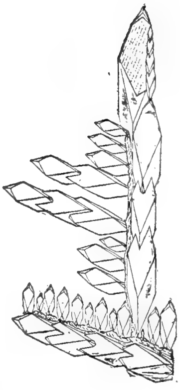
3.



The predominating form is uniformly this last mentioned acute rhombohedron; though traces of the pyramid can usually be seen. The simple crystalline threads are built up of a series of these rhombohedrons in parallel position and crowded closely together. This is shown in fig 4. The terminal crystal is often larger than the others, and frequently of the skeleton type with prominent salient edges and the larger part of the face depressed, and perhaps made up of a series of fine parallel wires of frosted gold, suggesting some of the most delicate ornaments made by a skillful worker in gold.

4.

5.



The threads, however, are not limited to a single line of parallel crystals; generally there are two lines close together with a depressed furrow between them, and a third in which the crystals are also in parallel position with each other, but elongated according to another octahedral axis. In these last cases each plane of a crystal in one line is parallel to one in the other, but these planes have a different value in the rhombohedral development. Figure 5 shows a string of these crystals branching off from another line at the bottom; here the second line of crystals parallel to the first is concealed from view, but the third is shown consisting of those elongated in the direction of the other axis. These last are represented as having the same rhombohedral development as the others, which is often true, but it is also common to find them with this elongation scarcely shown so that they deviate much less from the ordinary trisoctahedral form. These threads are then made up of the line or lines of sharp rhombohedral forms and this other line of minute bead-like crystals. These compound threads often taper down to a fine wire with crystalline markings on the surface but showing no distinct forms.

No fullness of description could give a satisfactory idea of the variety of these forms, as no drawing could adequately represent their beauty and delicacy. The arborescent branching forms are the most beautiful. Here we pass from examples where from a single stem a series of little lines run off, to others where the branching is again repeated, and yet again with such perfection that each individual crystal can be clearly made out. Other forms take the shape of a feather with a strongly defined central axis and with the fine threads branching from it on both sides at a slightly oblique angle ($o \wedge o = 70° 32'$). The central line is here normal to a plane 111, while the branches go off in directions normal to $1\bar{1}1$ and $\bar{1}11$ respectively; in all cases we have to do with parallel grouping only, and there is no necessity to appeal to twinning to explain the forms observed. The only distinct examples of this method of growth in gold, which the author has been able to observe, are these from the Oregon mine, with the exception of a single Hungarian specimen in the cabinet of Mr. Clarence S. Bement of Philadelphia, which appears to be developed in a similar manner.

2. *Gold from California.*

The gold mines of California have produced large numbers of specimens of finely crystallized gold, but unfortunately it is only rarely that they have been preserved. But little has been published upon the subject; a recent article somewhat popular in character, by W. P. Blake* of New Haven, is deserving of mention. The specimen to which the writer's attention was first directed belongs to the Yale collection, and is labeled as having come from Tuolumne County. It consists of a series of octahedrons in parallel position, and passing from the small solid crystals to larger ones with cavernous faces and their edges in ridges, and then to others looking as if they had been made of bent wire. In addition to the large octahedral faces (*o*), there

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* The various forms in which gold occurs in nature, 25 pp.; from the Report of the Director of the U. S. Mint for 1884.

are also prominent those of the trisoctahedron 3-3 (*m*), usually strongly striated; a hexoctahedron, one set of whose edges are apparently truncated by the trisoctahedron and traces of a second hexoctahedron. The determination of this first mentioned hexoctahedron, as will be seen, requires exact measurements, and on all the larger crystals the planes are not bright enough to be used on the goniometer. A single very small crystal ($\frac{1}{8}^{\mathrm{mm}}$ across) was found, however, on which these faces were brilliant though excessively minute. On this the three angles of the hexoctahedron were measured (with the usual compound goniometer), as also the inclination of a face upon the adjacent octahedral and trisoctahedral faces. Two independent measurements for different faces were obtained in each case. These measurements are liable to an error of from 5′ to 10′ in consequence of the want of sharpness of the images obtained, but they are accurate enough to prove beyond all question that the true symbol is 18-$\frac{9}{5}$ (18·10·1). This will be seen from the following comparison of measured and calculated angles:

	Edge A. 18·10·1 ∧ 18·1·10	Edge B. 18·1·10 ∧ 18·1·10	Edge C. 18·10·1 ∧ 10·18·1
Meas.	35° 50′, 36° 9′	5° 43′, 5° 41′	31° 53′, 32° 1′
Calc......	35° 58′	5° 34′	31° 51′

	x o 18·10·1 ∧ 111	*x m* 18·10·1 ∧ 311
Meas.	35° 44′, 35° 45′	18° 2′, 18° 10′
Calc.	35° 41′	18° 4½′

It will be seen that the agreement between measured and calculated angles is remarkably close, considering the nature of the faces. The goniometer also showed, independently of the calculations, that the trisoctahedral planes do not actually truncate the edges of the hexoctahedron, although the planes 18·10·1, 311, 10·18·1 do fall very nearly in a zone.

The positive determination of the form is of some interest, both because it is so common in the California crystals, as will be noted later, and because it was observed by Rose on specimens from the Ural many years ago. In his paper, already referred to, he remarks upon the occurrence of a hexoctahedron in conjunction with the dodecahedron, octahedron, trisoctahedron 3-3 and the hexoctahedron 4-2; he gives several figures, one of which has been copied in Dana's Mineralogy (f. 53, p. 3). The crystals examined by Rose* afforded only rough measurements, and to the symbol obtained 19-$\frac{19}{11}$ (19·11·1) he consequently did not attach very great importance.

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* Rose uses the letters *t* for this hexoctahedron and *n* for 4-2; the writer, following Miller, restricts the letter *m* to 3–3, *t* to 4–2, and uses *x* for the hexoctahedron 18-$\frac{9}{5}$.

It was suggested by Naumann,* that $15\text{-}\frac{5}{3}$ (15·9·1) was a more probable symbol, since it satisfied the measured angles about as well as the other, and at the same time was a form whose edges (A) were truncated by the common trisoctahedron 3-3 (311). This suggestion Rose was inclined to accept, and later writers have followed him (e. g. Klein).† A comparison between Rose's angles and those required by the form $18\text{-}\frac{9}{5}$ (18·10·1), positively determined on the California crystals, leaves no doubt that the latter symbol should also be given to Rose's plane since it satisfies the measured angles as well or better than either of the others suggested.

	Calculated. Edge B.			Measured. Rose.
For $19\text{-}\frac{19}{11}$	$15\text{-}\frac{5}{3}$	$18\text{-}\frac{9}{5}$		
5° 13′	6° 33′	5° 34′		5° 10 to 5° 41′
	Inclination on *o* (111)			
35° 28′	34° 32′	35° 41½		36° 50′ to 37° 10′
	On *d* (110)			
15° 9′	14° 24′	16° 11′		15° 30′ to 15° 50′

This is an interesting example of a case in which the so-called zonal law, so often employed to decide a doubtful symbol

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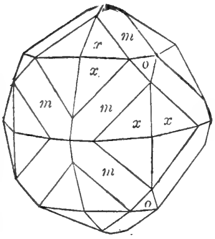

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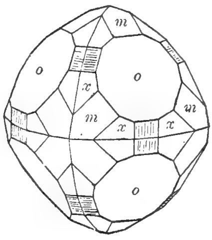

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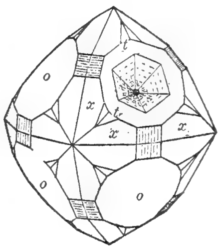

does not hold good. Figure 6 shows one form of the crystals now being described; another is given in figure 7 which also exhibits an additional point of interest. The octahedral edge is here, in some cases, apparently truncated by the dodecahedral plane, in others beveled by a pair of planes; closer inspection, however, shows that this edge is formed simply by an oscillatory combination of the adjacent planes of the hexoctahedron. In other crystals of more octahedral habit the edges are all thus finely striated. The faces of the trisoctahedron *m* are also, though not always, striated in a similar manner, and sometimes the place of the plane seems to be taken by this oscillatory combination of the hexoctahedral planes.

This hexoctahedron *x*, $18\text{-}\frac{9}{5}$, appears to be a common form

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* Pogg. Ann., xxiv, 385.

† Jahrb. Min., 1872, 129.

in the California gold. A beautiful specimen in the cabinet of Professor Brush from the Spanish Dry Diggings in El Dorado county shows it very plainly. This specimen consists of large crystalline plates bound together by a little quartz; the plates are in part solid with triangular markings on the surface, or hexagonal depressions made by the planes of this hexoctahedron, and in part consist of open work formed of delicate crystalline ribs branching at angles of 60° and 120°. These plates are essentially flattened octahedrons, and their edges are all formed by an oscillatory combination of the hexoctahedral planes, producing a fine striation similar to that on the specimen before described. Occasionally the edge is beaded with distinct crystals, and in cavities other crystals are to be seen, the small ones entire, or at most, with hexagonal pittings (figure 8), the larger ones, skeleton forms, as if formed of gold wire. Measurement proved the hexoctahedron to be the same as that already determined, while a second hexoctahedron *t*, 4-2 (421) is sometimes sufficiently developed to admit of determination.

The writer has recently had an opportunity to examine the fine series of crystallized gold in the cabinet of Mr. C. S. Bement of Philadelphia, and has observed a number of specimens showing the hexoctahedron 18-$\frac{9}{5}$ and very similar in habit to those described. Two of these specimens were from El Dorado county; another from Tuolumne county was octahedral in habit with the edges replaced in the manner described by the oscillations of x; still another from Yreka county showed several thin triangular plates with the striations on the edges, and with also hexagonal pittings formed by the planes of the same hexoctahedron. In the article by Prof. Blake, already alluded to, a description is given with figures of octahedral gold crystals, similar in form to those here mentioned. These crystals were from the Princeton mine in Mariposa county, and they agree so closely in form and habit with those here figured as to leave no doubt that the planes, if determined by measurement, would be found to have the same symbols.

ART. XVI.—*Classification of the Cambrian System of North America*;* by CHARLES D. WALCOTT.

THE formations included within the Cambrian system, in this paper, are those characterized by the predominence of the types of the "First Fauna"† of Barrande and such additional

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* Read before the National Academy of Science at Washington, D. C., April 23d, 1886.

† The "First" or "Primordial Fauna" of Barrande, as found in North America, is characterized by a trilobitic fauna which, in the presence of the genera Agnostus, Paradoxides, Olenellus, Dicellocephalus, Ptychoparia and their allied genera, distinguishes it from the succeeding Lower Silurian (Ordovician) fauna.

strata, not characterized by the presence of fossils, as are stratigraphically and structurally connected with Cambrian strata identified by organic remains.

Professor Geikie, in the last edition of his Manual of Geology (1885, p. 65), has included the Cambrian as a subdivision of the Silurian system. I do not *now* wish to question the wisdom of this for the geologic section as it occurs in England and the Continent; but of the presence of a well-defined geologic system beneath the Lower Silurian (Ordovician) strata characterized by the Second fauna of Barrande, or the Trenton fauna (including the Upper Calciferous) on the North American continent, there is little doubt. The geologic sections, given in this paper, show that it has a total thickness of over 18,000 feet and contains a known fauna of 92 genera, including 393 species; that but very few of these species pass up into the Calciferous horizon of the Lower Silurian (Ordovician), and that the faunas of the two systems are so distinct in their general facies and also in detail, that they are quite as readily separated as the Lower and Upper Silurian, Silurian and Devonian, or Devonian and Carboniferous faunas. There is no doubt that in certain areas the faunas of the Cambrian and Lower Silurian (Ordovician) systems are intermingled in the passage beds between the two systems, but the same is more or less true of all the great divisions of the entire geologic series, from the Archean to the Quaternary.

Strata of the Cambrian System.

In beginning the study of the Cambrian system, I looked for well-defined Paleontologic horizons with relation to which the various local sections and their contained faunas could be compared. It was evident that the Potsdam faunas of New York and the Mississippi Valley were at or near the summit of the Cambrian, but further than that there was little data. Mr. E. Billings called the Georgia or Olenellus fauna "Lower Potsdam," and considered the Paradoxides fauna as of older date: but, as late as 1885, one of our best-known paleontologists wrote: "my own impression, at the present, is that the New York typical Potsdam is about equivalent to the lower portion of the Wisconsin areas, and that the Acadian beds of Canada and Vermont, and perhaps the other Atlantic areas, are not appreciably different in age, but that the difference in faunas is more the result of conditions upon which life depended than a difference in time." (Bull. Amer. Mus. Nat. Hist., vol. i, p. 140, 1885.)

The results of the study of the Middle Cambrian faunas will appear in Bulletin 30, of the U. S. Geological Survey, and I have taken much of the data of this paper from the introduction of that bulletin. In establishing the stratigraphic position and paleontologic characters of the Georgia or Olenellus fauna of the Middle Cambrian, the key to the succession of the Cambrian faunas was obtained, and the sections that are correlated in the diagram (fig. 1) are placed on the general section with relation to the stratigraphic position of Olenellus and Dicellocephalus, or Georgia and Potsdam faunas.

1.

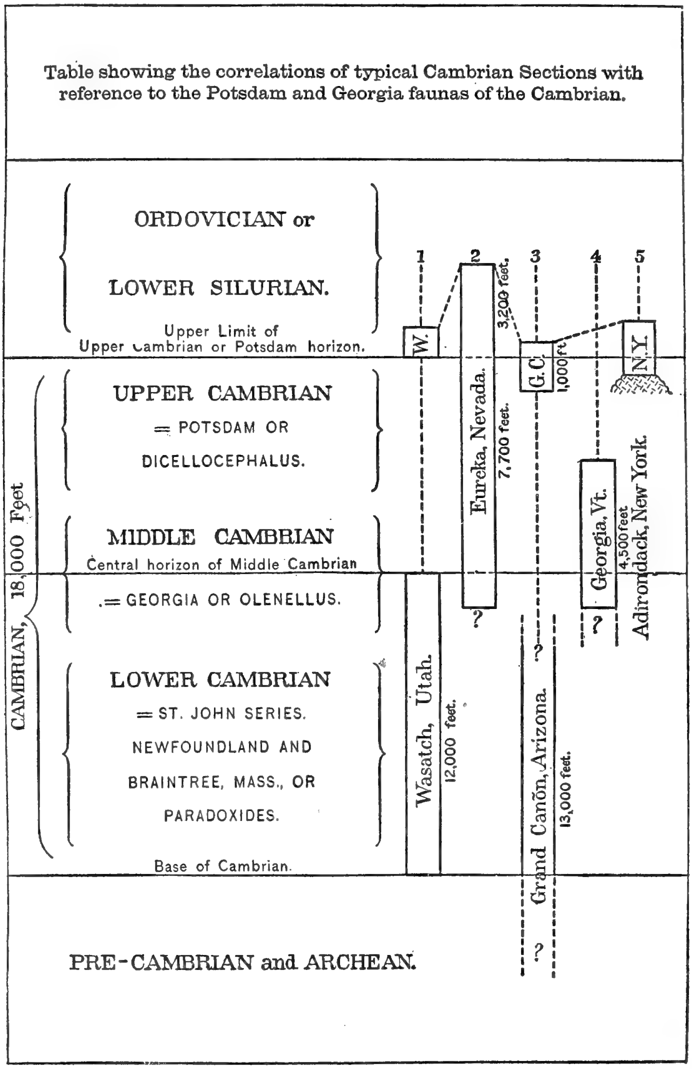

Table showing the correlations of typical Cambrian Sections with reference to the Potsdam and Georgia faunas of the Cambrian.

The first section (fig. 2) to which I wish to direct your attention is that of the Wasatch Mountains, in Utah, where the Cambrian is well shown in Big Cottonwood Cañon. The section is described in the reports of the Geologists of the Fortieth Parallel Survey (Geol. Expl. 40th Par., vol. i, p. 229; vol. ii, p. 366), but I had the opportunity of examining it more in detail during the summer of 1885, and through finding the

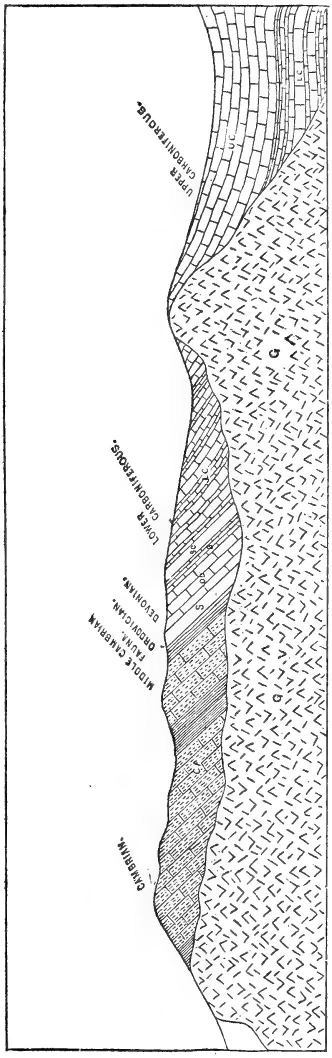

Fig. 2.—Wasatch section. This crosses the Wasatch Mountains a little south of Big Cottonwood Cañon. Copied from map of sections accompanying vol. i, Geol. Expl. of Fortieth Parallel. Scale, about 10,000 feet to the inch. The Cambrian strata are represented as resting unconformably on the granite and as overlaid by the conformable Lower Silurian (Ordovician) strata. The position of the Middle Cambrian fauna is indicated just below the Silurian horizon. CA, Cambrian; S, Silurian; OD, Devonian; LC, Lower Carboniferous; UC, Upper Carboniferous; G, Granite. Further study in the field will probably result in a somewhat different representation of this section, as it was originally based on rapid reconnaisance work by the geologists of the Fortieth Parallel Survey. The relations between the granite and the overlying strata are not as understood by myself, but are given as in the original section.

Olenellus or Middle Cambrian fauna, located its upper horizon and ascertained that the entire Upper Cambrian was absent by non-deposition, the Silurian resting conformably on strata of Middle Cambrian age. The section at the base rests on granite near the mouth of Big Cottonwood Cañon, and the strata continue up the cañon in an unbroken, conformable series of siliceous rock, shales, quartzites and sandstones, until 12,000 feet in thickness

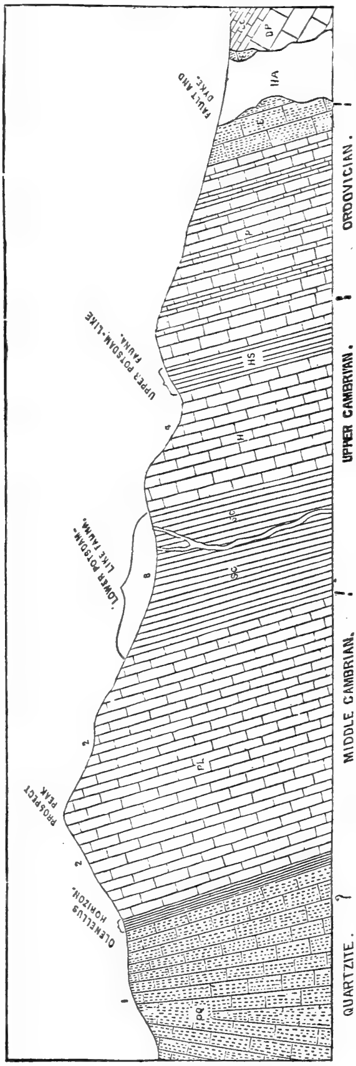

Fig. 3.—Eureka section. This extends over the Cambrian strata of the Eureka district and up to the base of the Trenton limestone horizon of the Lower Silurian (Ordovician). The numbers on the upper line correspond to the numbers on the divisions given in the descriptive section: 1 and PQ, Prospect Mountain quartzite; 2 and PL, Prospect limestone; 3 and SC, Secret Cañon shale; 4 and H, Hamburg limestone; HS, Hamburg shale; P, Pogonip limestone; E, Eureka quartzite; HA, hornblende-andesite; LC, Lower Carboniferous; DP, Devonian. The dike represented in the Secret Cañon shale is not continuous, and on the line upon which the fossils were collected it was not observed, the section being unbroken from 1 to the great dike beyond the Eureka quartzite. The section is copied from the unpublished map of sections, by Mr. Arnold Hague, illustrating the Geology of the Eureka district. Scale, 1,800 feet to the inch.

is passed through. In the upper 250 feet of silico-argillaceous shales that rest on a massive band of quartzite, 3,000 feet in thickness, the following fossils occur: *Cruziana?*, *Lingulella Ella*, *Kutorgina pannula*, *Hyolithes Billingsi*, *Leperditia Argenta*, *Olenellus Gilberti*, *Ptychoparia quadrans* and *Bathyuriscus producta*. This fauna is also found at a similar horizon in several localities in Nevada; and the lithologic, stratigraphic and paleontologic evidence, as found in the Oquirrh and Tintic ranges of Utah and the House, Eureka and Highland ranges of Central Nevada, extends the same horizons throughout the western and southern portions of the Great Basin area.

The entire absence of fossils in the lower portions of the Wasatch section may be owing to the character of the sediments; but an attempt is made further, to explain the absence of the Lower Cambrian fauna of the Atlantic area.

The second section (fig. 3), that of the Eureka District, by Mr. Arnold Hague, stratigraphically overlaps that of the Wasatch, the lower 1,500 feet of quartzite corresponding to the upper-half of the 3,000 feet of quartzite of the Wasatch section, and the Olenellus shales occurring at the same horizon on the summit of the quartzite; but here the Lower Silurian (Ordovician) strata do not rest on the siliceous Olenellus-bearing shales, but are separated by over 6,000 feet of limestone that carries a fauna uniting the Middle Cambrian fauna with the Upper Cambrian or Potsdam fauna, which begins in its characteristic forms 4,500 feet above the Olenellus horizon. One hundred miles south of Eureka, in the Highland Range, I found the Eureka section essentially repeated and identical species occurring at the same relative horizons in each section. The vertical range of the Eureka section embraces the corresponding strata of the Highland Range section and several sections that occur in Nevada and Western Utah.

Section No. 3, fig. 4, is unlike either of the first two sections in having the Upper Cambrian well developed, and the Middle, and probably the Lower Silurian (Ordovician), entirely absent. This section is beautifully exposed in the deeper portions of the Grand Cañon of the Colorado, Arizona, and was first made known in a general way, through the explorations of Major J. W. Powell in 1875. During the winter of 1882–83, Major Powell instructed me to make a detailed section of the strata in the depths of the cañon, and fig. 4 is one of the results of the work. The Upper Cambrian, or Tonto formation is 1,000 feet in thickness, composed of siliceous and calcareous strata and carries a fauna that unites it closely with that of the Upper Cambrian of Nevada, Texas and the Upper Mississippi Valley. Beneath the Tonto there is a great mass of strata, over 12,000 feet in thickness, that are unconformable to the horizontal Tonto strata above and the highly-inclined (Huronian?) strata beneath. I have heretofore referred the pre-Tonto series to the Cambrian and correlated it with the Keweenaw of Wisconsin and Llano series of Texas, but I am now inclined to call all these series pre-Cambrian and a system of equal degree with the Cambrian, Lower Silurian (Ordovician), etc. If this is done the strata below the Grand Cañon series will be correlated with the Huronian of the Wisconsin section. This will be referred to again.

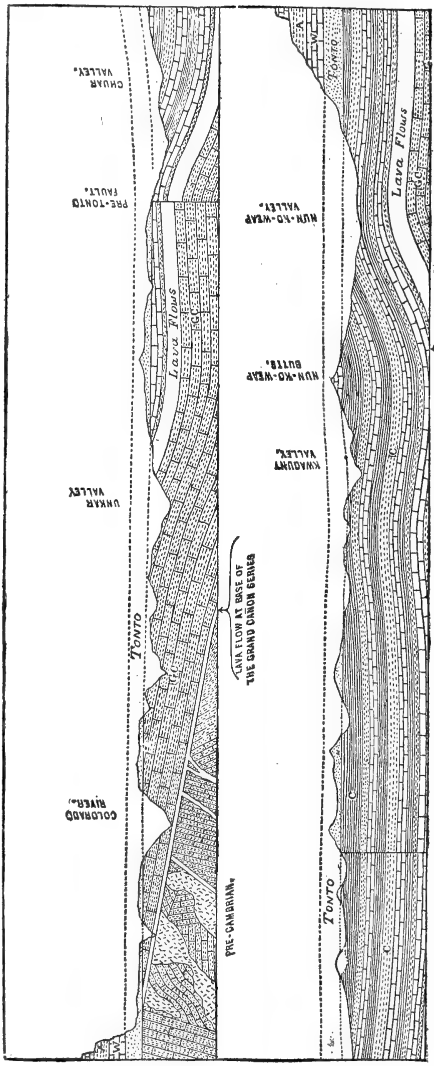

Fig. 4.—Grand Cañon section. The section represented by this figure crosses the pre-Tonto strata nearly at right angles to their strike as exposed in the Grand Cañon of Colorado, Arizona, and studied by the writer. Horizontal scale, 12,500 feet to the inch. Vertical scale about 8,500 feet to the inch. The Upper Cambrian (Tonto formation) has been removed by erosion on the direct line of the section, but is present, as indicated by the dotted lines, around the margins of all the cañons that cut it on the line of the section. GC, Grand Cañon formation (the lava flows also belong to this); T, Tonto formation; W, Red Wall Carboniferous limestone; A, Aubry Carboniferous sandstone (above this comes the Aubry Carboniferous limestone, which forms the outer wall of the cañon). All the strata beneath the Tonto formation are considered as pre-Cambrian.

The Grand Cañon section is typical and includes with it the Cambrian section of Central Texas and Northern Wisconsin (see figures 5, 6).

Crossing to the eastern side of the Continent, our next section (fig. 7, p. 148) of the Cambrian strata is taken in Northwestern Vermont, and its contained faunas serve to connect the distant Nevada sections and the group of Cambrian sections along the St. Lawrence, Champlain, and Hudson River Valleys.

At the base of the section a massive belt of limestone, 1,000 feet in thickness, carries in its upper portions the Olenellus fauna which, in the argillaceous shales capping the limestones, attains an extensive development. Continuing up in the section through the argillaceous shales, about 2,000 feet, masses of limestones are found interbedded in the shales, and in the limestone fossils that show the near approach of the Upper Cambrian or Potsdam fauna. The section gives the same succession of fauna as the sections of Nevada, where we find positive stratigraphic proof of the great difference in age of the Middle and Upper Cambrian faunas.

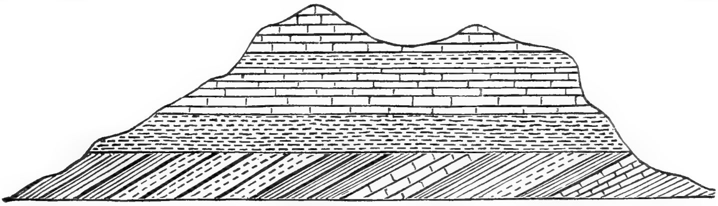

Fig. 5.—Section in Llano County, Texas, showing the relations of the Upper Cambrian (Potsdam) and the pre-Cambrian Llano Series.

The Georgia, Vermont, section includes, in its vertical range, the sections about and below Troy, N. Y., in the Hudson River Valley, and those of Northwestern Newfoundland and the Straits of Belle Isle.

Directly east of the Adirondack Mountains of New York, the Potsdam sandstone is overlaid by a stratum of shaly arenaceous rock full of fucoidal, or annelid markings, and there the Chazy limestones appear resting on the latter.* Tracing the sandstones south, a fine exposure is seen at Ausable Chasm, and continuing south a limestone is found coming in on top of the sandstone that, in Saratoga County, contains a well-marked fauna of twelve species, four of which are identical with species in the upper beds of the Wisconsin Potsdam sandstone. The calcareous layers of the Potsdam also occur at Whitehall, and Professor Dwight has found them near Poughkeepsie.

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* The unconformity, by non-deposition, noticed by Sir William Logan, is nowhere better illustrated than at this point, the Calciferous formation being absent from the section.

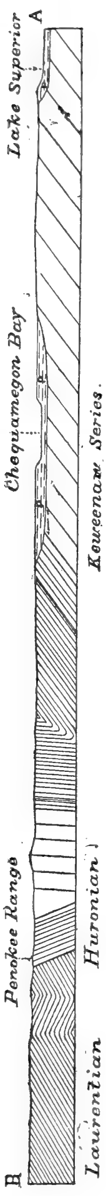

Fig. 6.—Section in Northern Wisconsin showing the relations of the Laurentian, Huronian and Keweenaw Series to each other and to the overlying Upper Cambrian (Potsdam) strata.

During the deposition of the Potsdam sandstone the shore-line was close at hand, and the Adirondack area furnished material for the formation. Out from the shore-line the mud and sand were mixed, and still farther out, over the present area of the Georgia section, the shales with interbedded limestones point to deeper, quieter waters. I have yet failed to find in Vermont any Potsdam sandstone north of Burlington; and the evidence goes to prove that the upper portion of the Georgia section, with its shales and "lentiles" of limestone, is equivalent to the Potsdam sandstone about the Adirondacks.

We have now hastily reviewed the principal sections of the Cambrian under which all the others now known can be grouped except those of Braintree, Massachusetts, St. John, New Brunswick and the southeastern Newfoundland sections. These are not connected paleontologically with the more western section and we distinguish them as the Atlantic border sections, and mostly of older date* than the strata of all but the lower portions of the Wasatch, and perhaps the Tennessee sections. As the position of the Atlantic border Paradoxides fauna is determined on paleontologic evidence, the discussion of it will be taken up later.

In the following table, the writer expresses his view of the classification of the various formations that go to make up the Cambrian system of North America. It is subject to revision in details, but the main divisions are based on paleontologic and stratigraphic data, that I think will render them of service in the permanent classification of American Paleozoic rocks.

It is not claimed that the arrangement of the formations in the following table is original with me, as, with some changes in nomenclature, it is the same as that to be found on page 46 of the Report of the Geological

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* At St. John, New Brunswick and also in Newfoundland, the higher members of the Cambrian system, containing the later Cambrian faunas are known, but, with our present information, the lower fauna predominates, and the upper faunas will probably prove to be more closely related to the Atlantic than to the interior basin, although we may expect to find a number of species common to each.

Classification of North American Cambrian Rocks.

UPPER CAMBRIAN.	Lower Calciferous.	Lower portion of the Calciferous formation of New York and Canada. Lower Magnesian of Wisconsin, Missouri, etc.
	Potsdam, Knox, Tonto.	Potsdam of New York, Canada, Wisconsin, Texas, Wyoming, Montana and Nevada: Tonto of Arizona; Knox Shales of Tennessee, Georgia and Alabama. The Alabama section may extend down into the Middle Cambrian.
MIDDLE CAMBRIAN.	Georgia.	Georgia formation of Vermont, Canada and New York.
	L'Anse au Loup.	Limestones of L'Anse au Loup, Labrador.
	Prospect.	Lower part of Cambrian section of Eureka, and Highland Range, Nevada. Upper portion of Wasatch Cambrian section, Utah.
LOWER CAMBRIAN.	St. John, Braintree, Newfoundland, Wasatch.	Paradoxides beds of Braintree, Mass., St. John, New Brunswick, St. John's area of Newfoundland, Lower portion of Wasatch section, Utah.
	Tennessee.	The Ocoee conglomerate and slates of East Tennessee are doubtfully included.

Survey of Newfoundland for 1865, published in 1866, by Sir William Logan, and based largely on the paleontological work of Mr. E. Billings.

Fauna of the Cambrian System.

As has long been well known, the Trilobita form by far the largest portion of the Cambrian fauna. Of the ninety-two genera and three hundred and ninety-three species known to me at present from the American Cambrian, 31 genera and 226 species are placed under the Trilobita, and 61 genera and 167 species under all the other classes. The Brachiopoda come next with 15 genera and 67 species; Crustacea with 10 genera and 15 species, etc.

In the accompanying table a summary is given of the Cambrian faunas of North America, as far as known to me, up to the present date. A critical study of the Upper Cambrian faunas will eliminate some of the genera and species and, also, add others. The study of the Lower Cambrian fauna of New Brunswick is now being carried forward by Mr. G. F. Matthew, and that of the Upper Cambrian by myself; and probably within two years the Cambrian fauna of North America will include more than 100 genera and 400 species, as to-day there are 92 genera and 393 species published, that I have included in the fauna. There are a number of genera and species not included that do not appear to be based on organic remains, or are synonyms of some of those that are included.

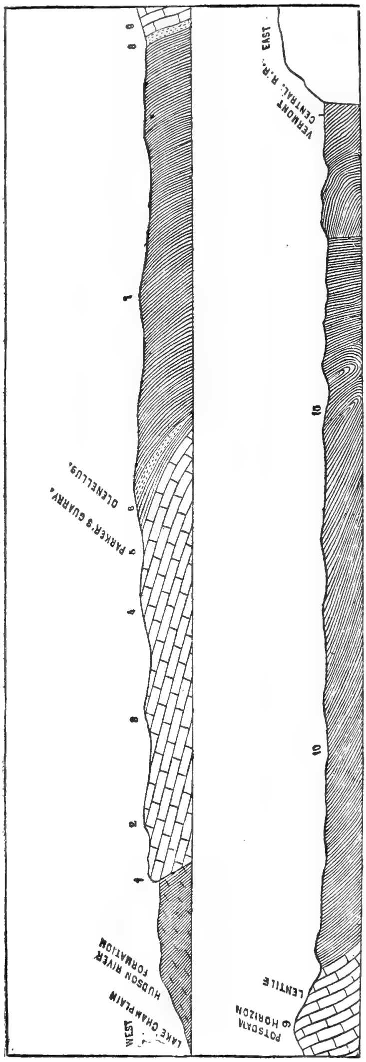

Fig. 7.—Georgia section. This extends from Lake Champlain east to the Vermont Central Railroad track, and passes through the Parker trilobite quarry, and a little south of the town of Georgia post office. Horizontal scale, about 2,000 feet to the inch.

The figs. 1 to 10 indicate the position of the lower strata of each of the divisions given in the descriptive section.

Geologic Résumé.

	Genera.	Species
Upper Cambrian	52	213
Middle Cambrian	43	107
Lower Cambrian	32	76
	127	396
Reappearances	35	3
Total fauna	92	393

Zoologic Résumé.

	Genera.	Species.
Algæ	3	9
Spongiæ	6	13
Hydrozoa	4	5
Crinoidea	1	3
Annelida	2	5
Brachiopoda	15	67
Lamellibranchiata	1	1
Gasteropoda	14	29
Pteropoda	5	20
Crustacea	10	15
Pœcilopoda	31	226
	92	393

There are 14 genera common to the Lower and Middle Cambrian; 15 common to the Middle and Upper Cambrian; 11 common to the Lower, Middle and Upper Cambrian, and 12 common to the Lower and Upper Cambrian.

Of the 52 genera in the Upper Cambrian, 17 are much more strongly represented in the second fauna, viz: Lingula, Orthis, Leptæna, Triplesia, Bellerophon, Euomphalus, Holopea, Maclurea, Metoptoma, Ophileta, Pleurotomaria, Hyolithes, Serpulites, Amphion, Bathyurus, and Ogygia.

Of the above genera, Discina, Pleurotomaria, Amphion, Bathyurus and Ogygia are doubtfully referred to the Cambrian. Several other genera pass up into the base of the Lower Silurian (Ordovician), but are not considered as at all characteristic of its fauna.

When an accurate stratigraphic and paleontologic study is made of the passage beds between the Cambrian and Lower Silurian (Ordovician) systems, or the Potsdam and Upper Calciferous formations of the New York and Canadian sections, we shall possess the data upon which to compare the faunas of the two systems. At present it is to a large extent wanting.

Stratigraphic position of the Upper, Middle and Lower Cambrian Faunas.—That the stratigraphic position of the Middle Cambrian fauna on the North American continent is below that of the Potsdam fauna is shown by the Eureka and Highland Range sections, in Nevada, and the Georgia section, in Vermont. In Nevada, in two sections unbroken by faulting or folding of the strata and separated by a geographic distance of one hundred and twenty-five miles, the fauna ranges from 2,000 to 4,000 feet below strata carrying a typical Upper Cambrian, or Potsdam fauna. But three species, *Protospongia fenestrata*, *Acrotreta gemma* and *Stenotheca elongata* are known to pass up to the Upper Cambrian or Potsdam horizon. In the Georgia, Vermont, section, one of the species, *Ptychoparia*

Adamsi appears to pass up into the Potsdam horizon of the section, where the fauna is more like that of the Potsdam; and of the other species, *Orthisina Orientalis* is much like *O. Pepina* of the Potsdam sandstone of Wisconsin; but the fauna, as a whole, is so clearly distinct from the typical Potsdam of New York, Wisconsin, Tennessee, Alabama, Texas, Arizona, Nevada and Montana that, even without any section to show their relations to each other, I should not think of correlating them as contemporaneous faunas.

The stratigraphic relations of the Middle Cambrian fauna to the Paradoxides fauna of St. John, Braintree and Newfoundland are not so clearly proven as for the Middle, and Upper Cambrian faunas. The only locality known where the two faunas are in the same geographic area is about Conception Bay, Newfoundland. At Topsail Head about 100 feet of limestone is exposed, overlaid by dark shale. All stratigraphic connection with other sections in the vicinity is broken. The fossils in the limestone are not numerous, but Mr. Billings pronounced them Potsdam (Geol. Newfoundland, p. 158, reprint of report for 1868), and identified *Salterella*, *Crania* (probably *Kutorgina*) *Labradorica*, and I found, in the collection of the Geological Survey of Canada, *Scenella reticulata*, *Stenotheca rugosa*, *Iphidea bella* and *Protypus senectus* var. *parvulus*, which gives six species that are also known from the Middle Cambrian horizon of L'Anse au Loup.* Special stress is placed by the writer on the occurrence of these fossils at Topsail Head, as it is in the midst of the Paradoxides basin. Mr. Alexander Murray correlated the Topsail Head limestone with that of other localities, and places it beneath the Paradoxides-bearing shales of St. Mary's Bay (on the page cited above), but without paleontologic or stratigraphic evidence that can authorize him to say more than that a supposed connection is indicated.

Not having stratigraphic evidence of the relation of the Georgia or Middle Cambrian fauna and the Paradoxides or Lower Cambrian (Ordovician) fauna other than that they occur in the same area and are not in the same stratum of rock, we turn to the faunas to aid us in the settlement of the question.

Of the thirty-two genera of the American Paradoxides horizon, fifteen pass up into the Olenellus horizon, viz: Arenicolites, Protospongia, Archæocyathus?, Eocystites??, Lingulella, Acrotreta, Acrothele, Kutorgina, Orthis, Stenotheca, Hyolithes, Agnostus, Microdiscus, Solenopleura, and Ptychoparia. Of these, eleven, Arenicolites, Protospongia, Lingulella, Kutorgina, Acrotreta, Orthis, Hyolithes, Stenotheca, Agnostus, Microdiscus? and Ptychoparia, continue on up into the Potsdam or

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* Mr. Billings called all the Middle Cambrian fauna "Lower Potsdam," which explains his referring the Topsail Head fossils to the Potsdam.

Upper Cambrian horizon, leaving but four genera that are alone common to the Middle and Lower horizons. One genus, Dendrograptus, is doubtfully identified in the Paradoxides horizon of New Brunswick that occurs in the Upper Cambrian, and is, as yet, unknown in the Middle Cambrian. The genus Agraulos is also found in the Lower and Upper, but not in the Middle Cambrian. Of species, not one of the 76 of the American Lower Cambrian fauna are known to occur in the Middle Cambrian fauna, which, with its 107 species, stands out clearly from the older fauna and also from the more recent Potsdam fauna, as but three of its species, *Protospongia fenestrata*, *Stenotheca elongata* and *Acrotreta gemma*, are known to occur in the Upper Cambrian, and 16 of the genera in the Middle Cambrian are not known to pass up into the Upper Cambrian or into the Lower Silurian (Ordovician) faunas. Not one species is known to be common to the *Lower* and *Upper* Cambrian horizons.

Having studied the Middle Cambrian fauna more thoroughly than that of the lower and upper horizons, I will speak of it on that account and, also, from the fact that its character and geographic distribution is not as well known as the other two.

As a whole, we notice that it combines the characters of the Lower Cambrian and Upper Cambrian faunas and yet is distinct from each of them. There does not appear to be an equivalent fauna in the Cambrian system of Europe either in Bohemia, the Scandinavian area, or in Wales; but from the Island of Sardinia, Dr. Bornemann has described a group of sponge-like bodies closely related, if not identical with *Ethmophyllum* and *Archæocyathus* of the American Middle Cambrian fauna; he also names *Kutorgina cingulata* which is found at this horizon both in Vermont and Labrador. A species of trilobite is referred to Olenellus, but I have not seen any illustration of it.

The conditions that developed the Middle Cambrian fauna appear to have been largely peculiar to the American continent. During the deposition of the St. John's series of the Lower Cambrian, or the Paradoxides strata, we learn from the European and Eastern American sections, that the fauna was essentially of the same type over the entire basin (Atlantic), and, from evidence known to date, that the fauna did not extend west of a line passing northeast through Eastern Massachusetts to New Brunswick and Newfoundland.

That there were deposits of sediment to preserve the fauna, if it extended westward, is shown by the thousands of feet of sediments below the Middle Cambrian faunas of Utah and Nevada.

From the data we now have, I think that during the existence of the greater portion of the Lower Cambrian (Paradoxides) fauna, a barrier existed that prevented its extension westward of the line mentioned; that towards the close of the time of the Paradoxides fauna that barrier was removed to the northeast, in the vicinity of Newfoundland, and the descendants from the Paradoxides fauna entered the westward seas and spread to the eastern and western basins and formed the Middle Cambrian fauna. What route was taken by the Middle Cambrian fauna after passing to the western side of the outer barrier is not yet traced, but I think from the indications we now have of a continental area, during Lower and Middle Cambrian time, in the central portion of the continent, that the fauna passed to the south around the southern end of the then existing land, and thence north along the west shore. In the Atlantic basin, the Paradoxides fauna persisted to a greater or less extent and mingled with the types of the Upper Cambrian fauna as in the Upper Lingula Flags of Wales.

If this is a correct interpretation of the evidence now known, we may look in vain in the central interior basin for the Paradoxides fauna of the Atlantic basin.

That there was life in the older Cambrian or pre-Cambrian seas of the central interior basin, there is no doubt, as we have found traces of it in the Grand Cañon section of Arizona; and the development of that fauna which from the stratigraphy is pre-Cambrian, is one of the problems awaiting solution.

During the Upper Cambrian (Potsdam of America; Upper Lingula Flags of Wales), the Atlantic and Pacific basins appear to have had free communication with each other, and the faunas now have a facies of the same general character.

The above views are, to a certain extent, theoretical, but the facts demand an explanation other than that the faunas of the Lower, Middle and Upper Cambrian were contemporaneous but in different geographic areas. That the upper and middle faunas were separated by a great interval, is shown by the sections in Nevada and Vermont; and that the middle and lower faunas were not contemporaneous is shown by the biologic evidence and the indirect evidence of the absence of the lower fauna in association with the middle fauna in the Newfoundland area, where they are now found in different strata, but a short distance from each other.

A diagram illustrating the Cambrian sections of America and Europe would show, in the former, that the sequence of life is divided more sharply into three great groups that, in the latter, are more or less broken up. First: by the nearly entire absence of the middle group, and secondly, by the commingling of the upper and lower groups in the European strata and possibly in the Atlantic border sections of New Brunswick and

Newfoundland. This subject will be treated in detail after the completion of the study of the Upper Cambrian faunas now in progress.

As previously mentioned, I have heretofore included the Grand Cañon and Llano series as, in part, of Cambrian age, and correlated them with the Keweenaw series (Bull. VI, Phil. Soc. Washington, p. 102, 1882). In adopting the view that all of these may be placed under a system of pre-Cambrian age, I think there is good reason for it in the presence of the great unconformity, by erosion, between the strata of the Keweenaw system* and the known Cambrian formations. An examination of the sections shows that in each of them there is a great series of disturbed and eroded strata overlaid by the horizontal beds of the Upper Cambrian ; and in the Keweenaw, and the Grand Cañon sections, this great series of strata is in turn separated from the formation below by an unconformity that, in the Grand Cañon, is very great, and in the Lake Superior area, sufficient to indicate an orographic movement previous to the deposition of the Keweenaw strata. All three of the sections (figs. 4, 5, 6) agree in the evidence of an extended orographic movement and a great period of erosion at the close of deposition of the Keweenaw series; and I am now of the opinion that the Keweenaw system should be considered as pre-Cambrian. The correspondence in the position of the pre-Grand Cañon strata, separated from the Grand Cañon series by a great unconformity, to the Huronian as described by Irving, is so striking that more than calling attention to it is unnecessary.

The presence of organic remains does not necessarily imply that the strata are of Cambrian age except they show a marked Cambrian facies; and unless this is the case I should not contend for a moment against well-proved stratigraphic evidence of greater age and marked structural breaks in the stratigraphic succession. It may be asking too much for the period of erosion, between the Keweenaw system and the Upper Cambrian, to say that 12,000 feet of mechanical sediments and 4,000 feet of limestone accumulated in the Utah-Nevada basin while this erosion was taking place; but, if we look higher up in the Grand Cañon section, and that of Central Nevada, we find that 200 feet of Silurian and Devonian strata in the former is repre-

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* The Keweenaw system is here used to include the Keweenaw series of the Lake Superior region, the Llano series of Texas and the Chuar and Grand Cañon series of the Grand Cañon of the Colorado, Arizona, and is considered as of equal value with the Cambrian, Lower Silurian (Ordovician), Upper Silurian and other systems of the Paleozoic Group, and as belonging to the Paleozoic rather than to the Archean. It may be that the Keweenaw and Grand Cañon series belong to distinct systems of strata, but until this is proven I prefer to provisionally refer them to a pre-Cambrian post-Huronian system. I think the Grand Cañon and Llano strata belong to one system.

sentative of the 13,000 feet of limestone of the same formations in Nevada, and no unconformity, by any extensive erosion, is indicated; and, again, the 9,000 feet of limestone of the Upper Cambrian and Lower Silurian (Ordovician) of the Central Nevada section is unrepresented in the Wasatch section of Utah. These facts readily prepare us to believe that the hiatus between the Keweenaw and Upper Cambrian is fully equivalent to the period of the Lower and Middle Cambrian.

Another reason is that from the extended orographic movement preceding the erosion of the Cambrian, we should expect to find evidence of that erosion in the Cambrian of Utah and Nevada, but, as yet, none such is known.

Thus far the question of the existence of the Keweenaw system has been treated from a purely structural basis,* but, in the course of my study of the distribution of the Cambrian faunas, I have met with some facts that require an explanation and the most plausible one demands the existence of an extended orographic movement, prior to the deposition of the Cambrian strata of the western side of the Continent, that raised a land area over the central portion of the Continent which existed up to the period of the beginning of the deposition of the Upper Cambrian formations, when it was depressed beneath the level of the sea and the Upper Cambrian strata deposited over portions of it.

The facts demanding explanation are: 1st. The entire absence, as far as known to date, of the Lower Cambrian or Paradoxides fauna west of the Atlantic border: 2d. The absence of the Middle Cambrian or Olenellus fauna over areas occupied by the formations of the Keweenaw system.

If we accept the view that the Keweenaw, Grand Cañon, and Llano strata are outcrops of a system of strata of pre-Cambrian age that extended, in connection with the Huronian and Laurentian beneath it and projecting up through it, from the great body of Archean land on the north, southward over the area now occupied by the central portions of the Continent, or the Mississippi Valley, and westward to the area occupied by sediments accumulated on the western side of the Keweenaw system of strata when the latter formed a land area, then the explanation asked is given. The pre-Keweenaw portion of this Keweenaw land must have been extensive as, in the Missouri area at St. Louis and the Ozark Mountains, the Archean appears beneath the Upper Cambrian; and all the eastern slopes

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* Professor T. C. Chamberlain gives a most excellent summary of the Keweenaw series and its stratigraphic position in vol. i, of the Geology of Wisconsin. In the section, on page 65, it is placed as a distinct system, resting unconformably on the Huronian which, in turn, is separated from the Laurentian by an unconformity. The Cambrian is shown above the Keweenaw as a system between it and the Lower Silurian (Ordovician).

of the Rocky Mountains of Colorado show only the thin Upper Cambrian formations resting on the Archean; and the same is true in the Black Hills and in Central Wyoming. The existence of these Archean areas with the Upper Cambrian deposits proves the early date of their elevation, and that they

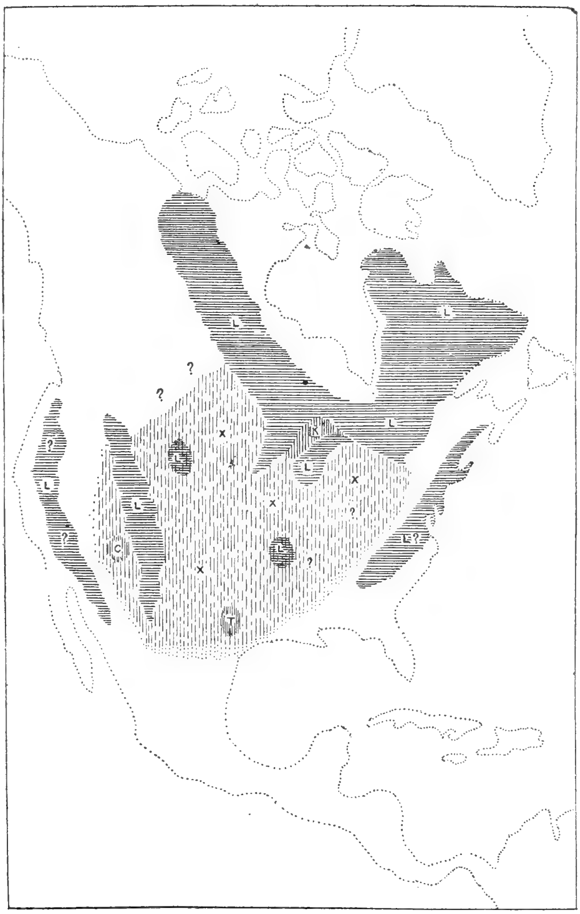


Fig. 8.—Hypothetical map showing the supposed Keweenaw land or continent as it existed just before the deposition of the Upper Cambrian (Potsdam) sediments. The latter probably extended over most of the area marked X, X, X, although now concealed by the later sedimentary deposits. The age of the eastern and western belts, marked L?, is still in doubt, but the presence of the eastern belt is strongly indicated by the geographical distribution of the Cambrian faunas. L, Laurentian and other Archean formations; K, Keweenaw; T, Llano formation; C, Grand Cañon formation; X, X, X, area supposed to have been land surface but now concealed by later deposits.

were the shore line of the pre-Cambrian Keweenaw sea. What the eastern boundaries of this sea were, we do not now know, but the inference, from what is known of the Archean of the Appalachian system, is that portions of the latter were above the ocean during the deposition of the Keweenaw system.

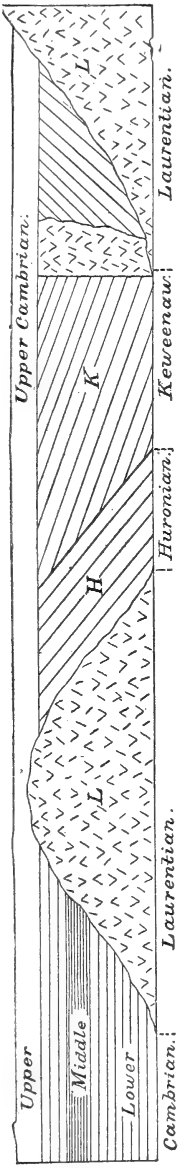


Fig. 9.—Ideal section to show the relations of the Upper Cambrian (Potsdam) strata to the old Keweenaw land. The Middle and Lower Cambrian strata are shown resting against the slope of the old Keweenaw continent, and the Upper Cambrian extending over it. The section is diagramatic, but may give the views of the writer to the reader more clearly than the description in the text.

The traces we now have of this Keweenaw land point to its extension from the Lake Superior region south to Central Texas and westward to Central Northern Arizona. A glance at the map (fig. 8) shows how far apart the relatively small exposures are; but, the great similarity of the sections and their position in relation to the Upper Cambrian that rests on the eroded surface of each visible area, points to a wide spread orographic movement that raised the entire central portion of the Continent and again depressed it at the termination of the period of erosion preceding the deposition of the Upper Cambrian or Potsdam sediments of the Upper Mississippi Valley, Central Texas and Arizona.

The existence of such a land over the area mentioned, is shown by the sections we now know; and I think that, when the areas of Cambrian and Archean rocks in Missouri and also along the Southern Appalachian chain come to be studied with the view that such a land existed during the period of the deposition of the earlier deposits of the Cambrian system, evidence will be forthcoming to show its former presence over a large area. On the north it probably joined the Archean continent and thus gave a greater extension of the pre-Cambrian continent to the south that, during the early history of the Cambrian period, furnished more or less of the sediments of the strata of the Lower and Middle Cambrian. The Archean boundaries of the Keweenaw sea continued after the elevation of the Keweenaw land. When Keweenaw land is spoken of, I refer to that formed of the strata of the Keweenaw system and the Archean rocks with which it was associated.

Before the Keweenaw land was depressed the Middle Cambrian fauna passed through or around the barriers between the Atlantic and western seas, and, as the Keweenaw land was disappearing beneath the waters, the Upper Cambrian fauna spread over the area occupied by it and left its record to aid us in fixing the geologic date of the submergence of the Keweenaw land and to explain the absence of the Paradoxides or Atlantic fauna in the early Cambrian strata of the western side of the Continent. In the diagramatic section (fig. 9), I have endeavored to show the relations of the Potsdam or Upper Cambrian to the Keweenaw land.

The evidence of the existence of the Keweenaw land is both stratigraphic and paleontologic. That life existed in the seas at the time of the deposition of the sediments of the Keweenaw system, is shown by its presence in the Chuar formation of the Grand Cañon series.

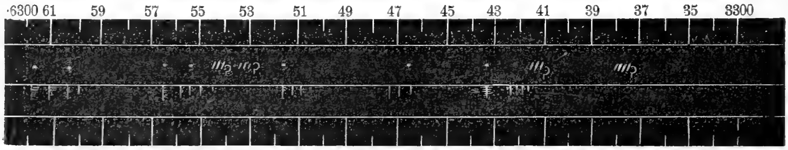
It may be urged that there is too much theorizing, on insufficient data, in the preceding statements, but, while waiting the accumulation of evidence it is well to have a working theory and as such the "pre-Cambrian Keweenaw land" is proposed, and the fragmentary remains, less the Archean portions, called a "pre-Cambrian Paleozoic System."

ART. XVII.—*Note on the Spectrum of Comet C*, 1886; by O. T. SHERMAN.

COMET C, 1886, presents to telescopic view, a faint oval of light about one and a half minutes in diameter. In the north proceeding quarter is a poorly defined condensation. Although well situated for observation, it is yet not especially suited for spectroscopic analysis; still out of curiosity the equatorial of the Yale Observatory was turned thereon. The result is not without interest: no less than seven loci of light present themselves, where three are usually seen.

On account of the circumstances it is necessary to describe somewhat in detail the apparatus and mode of observation. The comet's light focused upon the plane of the slit by the object glass of the equatorial (8 in.), and passing through the collimating lens falls upon a Rowland's flat grating, 14,347 lines to the inch, and is then focused for observation by a small telescope with low power eye-piece. The grating is fastened to an arc moved by a tangent screw, allowing the successive spectra to be observed as far as the D line in the fourth spectrum. The screw carries a rider bearing a double recording apparatus. The instrument being then pointed to the star, the observer brings portion after portion of the spectrum before the eye-piece. When he is fully convinced that a patch of light is before him, it is brought up to a thick cross wire, an automatic record made and the screw again turned till the observer is again convinced that an image of the comet is before him. Throughout the whole operation no light other than that of the comet was admitted. The information to be gained from the color of the image is, for faint light, very slight, and save such information, the observer's whole knowledge of his work is bounded by the fact that he started from a certain spectrum-place and will be stopped when he reaches a certain spectrum-place. Datum lines afforded by salted alcohol flame or Plücker tube, are finally added to the record. The record being withdrawn the observer has before him a double series of positions. By means of the datum lines these are converted into wave-lengths. If the same line is found in four out of six spectra it is set down as observed, if less than four, it is classed as suspected. If observed on every day of observation the reality of the line is accepted, if missed on some occasions it is only suspected. The faintness of the comet's light renders these precautions necessary.

Wave-length in ten millionth millimeters.



Spectrum of Comet C, 1886, *and spectrum of low temperature Carbo-hydrogen.*

To such a process the spectrum in question was subjected on May 26, 28, and June 4. The operation was repeated through the first, second, and third spectra, and again through the third, second, and first. The resulting loci have the following approximate wave-lengths: 618·4, 600·6, 567·6, 553·7, 517·1, 468·3, 433·2, with strongly suspected loci at 545·4, 535·0, 412·9, and 378·6. These positions may be in error by one or two units. It is of interest to compare them with the following, given by Hasselberg* as the chief lines of the Hydrocarbon spectrum: 618·7, 599·7, 563·4, 553·9, 5472, 516·4 469·7, 431·1. Of these loci 553·7, 517·1, 468·3, may well be the bands common in cometary spectra; 567·6 not uncommon, while 618·4 and 433·2 are probably those suspected by at least two

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* Ueber Die Spectra der Cometer Dr. B. Hasselberg, p. 21.

observers in comets B and C, 1881,[*] and by Secchi[†] in comet 1111, 1874. In carbon spectra and comet spectra also bands in the violet and ultra violet 414–420, 385–389, are photographed.

The comparison of this spectrum with the low temperature spectrum of carbo-hydrogen[‡] is not without interest. The distance of the comet from the sun was greater than 1·5. It may perhaps be suggested that the difference between this spectrum and that usually observed is due to temperature. It would be well if we had for the carbon compounds, a chart at successive heat levels, after the manner of that drawn up by Lockyer[§] for the photographed spectra of some carbon compounds.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Combustion of Carbon monoxide and Oxygen.*—LOTHAR MEYER has repeated the experiments of Dixon upon the non-inflammability of a perfectly dry mixture of carbon monoxide and oxygen, by means of the electric spark. The monoxide was prepared from magnesium formate and sulphuric acid and was shown by analysis to be pure. It was mixed with pure oxygen and in the first experiment was carefully dried for twenty-four hours with phosphoric oxide in the eudiometer. The ordinary spark of an induction coil failed to ignite the mixture; but using the primary coil of a moderately large inductorium with four large bichromate cells, ignition took place at 443^{mm} pressure. In the second experiment, the drying was continued for the same time. The mixture ignited by the spark under a pressure of 275^{mm}, but the explosion was incomplete; on increasing this pressure to 427^{mm} a second explosion took place, all the CO being burned. In the third experiment, the gas mixture was dried for six days and the sparks were continued for two minutes under a pressure of 156^{mm}. The combustion was complete. Meyer concludes therefore that carbon monoxide is not absolutely uninflammable under these conditions, but only difficultly inflammable. Moreover, since Dixon had observed an incomplete union with a series of sparks and a complete one when an ignited platinum wire was placed in the gaseous mixture, the author is of opinion that Dixon's results as well as his own are in accordance, and are all to be explained simply by difference of temperature in the spark; reduction of CO_2 to CO and O taking place when the spark is feeble, and oxidation of CO to CO_2 when it is strong.

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[*] Monthly Notices Roy. Astr. Soc., Nov. 1881, p. 15.

[†] Memorie dei Spectroscopiste Ital., vol. iii, 1874, p. 118.

[‡] Micrometric Gaseous Spectra. Piazzi Smyth.

[§] Proceedings Royal Society, vol. xxx, p. 463.

When intermediate in strength, both actions may go on together and the gas appear to be unchanged.—*Ber. Berl. Chem. Ges.*, xix, 1099–1106, May, 1886. G. F. B.

2. *On the Combustion of Cyanogen.*—DIXON has studied the conditions under which a mixture of cyanogen and oxygen gases is exploded and has reached the conclusion that the explosion depends solely upon the nature of the spark itself. The spark from the Holtz machine failed entirely to explode dry mixtures of these gases. The induction spark failed to explode the mixture in the eudiometer where the wires were 0·25 to 1^{mm} apart; but the explosion was violent in the tubes when the wires were 1 to 3^{mm} apart, and this was quite as true when the gases were moist. He then compared the explosion rate of this mixture with that of carbon monoxide and oxygen, using for the purpose a tube ten feet long and recording the time on a pendulum-chronograph. The velocities obtained were as follows in meters per second: cyanogen and oxygen, dried with phosphoric oxide, 813, dried with KOH 808, saturated with moisture at 15°, 752. Carbon monoxide and oxygen dried with P_2O_5, 36; with H_2SO_4, 119; saturated with moisture at 10°, 175; at 35°, 244; and at 60°, 317. It is noticeable that in the latter case the explosion-rate increases rapidly when a trace of moisture is added to the mixture; while in the case of cyanogen the presence of water vapor causes a slight fall in the rate. When a platinum wire is heated in the cyanogen mixture to dull redness, the coil cooled without result when the circuit was opened. But when raised to full redness it glowed brightly for half a minute after the current was broken and orange fumes were observed in the tube. About three-fourths of the cyanogen had been converted into CO_2 and one-fourth into CO.—*J. Chem. Soc.*, xlix, 384–391, May, 1886. G. F. B.

3. *On the so-called Critical Pressure in Solids.*—V. RICHTER has discussed the phenomenon of the non-fusibility of solids under certain conditions of pressure. Lothar Meyer had shown that iodine may be fused by heat or not according to the pressure upon it. Carnelley, who studied the same phenomenon in ice, regarded the fusion as conditioned upon a certain minimum pressure, which he called the "critical pressure," and which he defined as that external pressure at which no amount of heat will fuse the solid. According to Pettersson, the critical pressure of a substance is the pressure at which the boiling point of its liquid and the melting point of the solid coincide. The author reasons that as a liquid can exist as such only when the pressure upon it is greater than the tension of its vapor at that temperature, it follows that a fusible solid under a less pressure than the vapor tension at the fusing point cannot be melted, but on heating will pass directly into the state of vapor. A solid body, then, will evaporate without fusing whenever the pressure upon it is less than the vapor tension at the fusing point. Hence he suggests that the term "fusing-point tension" is a better term than

"critical pressure," especially since the latter is already in use in another sense to indicate the pressure at the critical temperature of liquids. Whenever the fusing-point tension of a body is greater than the atmospheric pressure, the substance is fusible only by increasing the pressure upon it. This is the case with arsenic, arsenous oxide, perchlorethane and carbon dioxide. The vapor tension of CO_2 at its fusing point (—65°) is three atmospheres. Hence solid carbon dioxide, under a less pressure, cannot be melted but passes directly into the gaseous state. This explains the fact that on issuing from the containing vessel, liquid carbon dioxide becomes either solid or gaseous at once, the pressure being below that at which the liquid can exist: i. e., below the fusing-point tension. On the other hand, whenever the fusing-point tension of a substance is less than the atmospheric pressure, the phenomenon of non-fusibility can be produced only by reducing the pressure. At 0°, the tension of water and ice is $4{\cdot}6^{mm}$. Hence below this pressure, ice is not fusible. So for all substances the maximum pressure is determined by the fusing-point tension. According to Regnault, the tension of benzene at 5° (its fusing point) is $35{\cdot}6^{mm}$. Hence below this pressure, solid benzene cannot be melted even by the most rapid heating. Experiment completely confirms this prediction. On account of the less perfect vacuum required and because of its less heat of fusion, this substance is admirably suited to exhibit the phenomenon in question. A strong flask having a lateral tube by which it is connected with a water pump, contains a few cubic centimeters of benzene, in which is placed a thermometer passing through the cork. The benzene having been solidified in a freezing mixture, the flask is exhausted below $35{\cdot}6^{mm}$ of mercury and heat is applied. No fusion can be observed. The experiment is facilitated by placing between the flask and the pump a tubulated receiver cooled by ice, whereby the benzene vapor is condensed and the vacuum is maintained. On the question whether the temperature of the solid thus heated ever rises above its melting point, the author calls attention to the fact that with solids as with liquids, a definite vapor tension corresponds to a fixed temperature, each temperature having its own tension. Thus mercuric chloride, which has a fusing-point tension of 420^{mm}, has at 200° a tension of 20^{mm}; at 240°, 130^{mm}; at 265°, 250^{mm}; and at 270°, 370^{mm}. So iodine, whose fusing-point tension is 90^{mm}, has a tension of 20^{mm} at 85°, of 30^{mm} at 90°, and of 75^{mm} at 110°. Since therefore the temperature controls the tension, the fusing-point tension must be a fixed quantity and the temperature invariable. Moreover at lower pressures, solids can be heated only to temperatures corresponding to the given tensions.—*Ber. Berl. Chem. Ges.*, xix, 1057–1060, May, 1886.

G. F. B.

4. *Studies from the Laboratory of Physiological Chemistry, Sheffield Scientific School of Yale College for the Year* 1884–85. Edited by Professor R. H. CHITTENDEN. 198 pp. 8vo. New

Haven, 1885.—This large volume is an important contribution to Physiological Chemistry, and is itself the best commendation of the organization of a laboratory in which so large an amount of good work could be accomplished in a single year. The papers included are eleven in number; one of these by Professors Chittenden and H. E. Smith gives the results of a quantitative study of the diastatic action of saliva as modified by various conditions; another by the same authors shows that the absorption of arsenic by the brain is limited to cases when soluble forms of arsenic have been administered. Other papers discuss the modifications of the amylolytic action of saliva and of the diastase of malt under various conditions, also the influence of various salts and other substances upon the proteolytic action, and kindred topics.

II. GEOLOGY AND NATURAL HISTORY.

1. *Geological Survey of Pennsylvania.* Report of the Progress of the Survey for 1885, by the State Geologist, J. P. LESLEY. Harrisburg, 1886.—Professor Lesley, in this chapter from his Annual Report, reviews briefly the work of the survey since 1874, when it began. By the close of 1885, 67 volumes of reports in 8vo had been published; the survey of the counties was nearly completed, 57 large colored geological maps and two uncolored of the 67 counties had been published; an octavo hand-atlas which contains colored geological maps on a small scale of all the counties; besides several parts of the atlas of the Anthracite region and numerous detailed maps and sections in the volumes of text.

In 1885, the appropriation for the years 1885–1886 was unfortunately reduced to only $25,000 a year, one-half the previous allowance; and at the same time the legislature asked for a new survey of the oil, gas and coal fields of western Pennsylvania. This crippling of the survey in its resources when doubling on its duties was of the worst kind of economy, especially for a State whose resources are so vastly mineral and geological in nature. Still, a large amount of work was accomplished in 1885, which awaits publication.

The survey has been ably conducted, and has had, with Professor Lesley at the head, an excellent corps of geological workers. It has been pushed forward with energy and produced great and admirable results, and those engaged in it merit the confidence and thanks and generous support in whatever plans for the completion of the survey the director may present. This report is prefaced by a beautiful colored geological map of the State of Pennsylvania which in itself speaks a strong word for the survey.

2. *Volcanic Eruption in New Zealand.*—The region of the New Zealand volcanic eruption in June last (between 1 and 2 o'clock on the morning of the 10th), is northeast of the center of the broad part of the North Island near lake Tarawera. The chief seat of the eruptions was in Mt. Tarawera and its vicinity on the east

side of this lake; but great fissures were opened widely, and the small lake of Rotomahana was converted into an area of geysers and cinder craters, a dozen or more having been suddenly put into action, the geysers throwing up water and mud, and the craters steam and stones and clouds of ashes. Mt. Tarawera is known to have consisted of volcanic rocks, but not as a volcano, or as containing a crater. Its summit was a sacred place with the natives where no foreigner was permitted to intrude. The eruptions from the Mt. Tarawera region as far as reported were of stones and ashes, nothing being yet known as to ejected lavas. The ashes have buried deeply the country around, destroying the village of Waroa and others beyond recovery, and causing the death of more than a hundred persons, among whom were some English settlers. The region of the eruption is comprised within the large geyser area of New Zealand, which extended from that of Tarawera and Rotorua southwest to Mt. Tongariro. A good map of it and an account of the geysers is contained in Dr. Peale's Report on Geysers, Hayden's Geol. Survey, for 1878, and republished in 1883, at p. 313.

3. *New Minerals.*—Professor A. WEISBACH has recently published a description of the interesting new mineral, called by him ARGYRODITE, in which the new element Germanium has been discovered (this Journal, xxxi, 308). Argyrodite crystallizes in the monoclinic system; the crystals are small and often united in rounded groups, so that they do not allow of exact measurement. The prominent planes are the prism with an angle of 115°, a clinodome $(1\text{-}\grave{\imath} \wedge 1\text{-}\grave{\imath} = 120^\circ)$ and a negative hemipyramid $(-1\text{-}\tfrac{2}{3} \wedge -1\text{-}\tfrac{2}{3} = 130^\circ)$; the axial relation deduced is $\grave{a} : b : c$ (vertical) $= 1 : 1{\cdot}67 : 0{\cdot}92$. Twin crystals and drillings are common, united so that the vertical axes are inclined 112° to each other. The physical characters are: hardness=2·5; specific gravity=6·093—6·111; luster metallic; color steel-gray with a tinge of red on the fresh fracture, tarnishing on exposure; streak grayish black, shining; no cleavage, rather brittle. An analysis by Winkler afforded:

S	Ge	Ag	Fe	Zn
17·13	6·93	74·72	0·66	0·22=99·66

Argyrodite occurs as a crust upon marcasite and siderite, or again on argentite; other associated minerals are sphalerite, galena, pyrite and chalcopyrite, and also the silver minerals pyrargyrite, polybasite and stephanite. The locality is the Himmelfürst mine near Freiberg.

ARMINITE is another new name given by Weisbach to a hydrous sulphate of copper found on porcelain-jasper from Planitz, near Zwickau, where it has been formed in the course of the burning of a bed of coal. It forms a green coating resolved by the microscope into short needles or scales. The material analyzed was scanty and more or less impure; the analysis, regarded as the most reliable, gave Winkler:

SO_3	CuO	Fe_2O_3, Al_2O_3	CaO
24·43	56·81	0·35	0·56=82·15

Assuming the loss to be water, the formula $Cu_6S_2O_{11}+6H_2O$ is deduced. On the basis of some new analyses of herrengrundite, the author concludes that its true formula is $Cu_4CaS_2O_{11}+6H_2O$, or like that deduced for arminite with an atom of copper replaced by calcium.—*Jahrb. Berg-Hüttenwesen*, 1886.

4. *The Zoetrope applied to crystallographic transformations;* prepared by Professor R. H. Richards. (Milton Bradley & Co., Springfield, Mass.)—This is an ingenious and effective application of the zoetrope to the illustration of the relation between certain isometric crystalline forms, exhibiting the gradual passage of a cube into the octahedron, the dodecahedron, etc.; also similarly in the case of hemihedral forms. The beginner in the subject will be much interested and instructed by this new use of the "wheel of life."

5. *Sketch of the Flora of South Africa;* by Harry Bolus, F.L.S. Separate issue from the Official Handbook of the Cape of Good Hope. 8vo, pp. 32.—A very interesting outline sketch of the prominent features of the Botany of the Cape of Good Hope, by one to whom they are most familiar,—a district from which Linnæus was ever receiving "something new," from which the first novelties were received in Holland nearly 250 years ago, and where new species still reward the search of the diligent collector. For South Africa—that is, the portion of the continent south of the Tropic of Capricorn—is perhaps richer in number of species and of genera than any other part of the world of the same area. According to Mr. Bolus, proximate causes of this great richness "appear to be: 1, the meeting and partial union of two (perhaps three) distinct floras of widely different age and origin; 2, a highly diversified surface of the land and of the soil; 3, a climate with much sunlight (or little cloud), a condition which seems everywhere favorable to the multiplication of forms." Of the 200 phænogamous orders of the latest Genera Plantarum, South Africa reckons 142; of the 7,569 admitted genera, it has 1,255. The southwestern district, the home of the "Cape flora" proper, which has longest been known, "an angular littoral strip," of which "the greatest width does not exceed eighty miles, and probably averages not more than fifty miles," in which "the rivers are few and badly supplied with water except in winter," a country of low-growing shrubs, with hardly a tree over 25 or 30 feet high, and these only in the ravines or the mountain-sides; yet this restricted district is thought to contain 4,500 species of flowering plants. This is the home of the "cape bulbs," of 350 species of true Heaths, of a great number of "immortelles," as well as of other less notable Compositæ, of the Pelargoniums which we cultivate as "Geraniums," of Proteas and the Silver-tree, and of the so-called Calla Lily, there as abundant in all moist-lying ground as the common dock in English ditches. How unlike this flora is from any northern one, may be seen in the names and sequence of its ten largest orders, which rank as follows: Compositæ, Leguminosæ, Ericaceæ, Proteaceæ, Iridaceæ, Geraniaceæ, Gramineæ, Cyperaceæ, Restiaceæ, Liliaceæ.

A notable peculiarity of the Cape vegetation, which Mr. Bolus dwells upon, is "its power to resist the aggression of foreign invaders." Little over a dozen foreign weeds are sufficiently abundant to attract attention, and most of these only within ten miles of Cape Town, which has been a European settlement for between three and four hundred years. In this respect it is most unlike insular floras, and not very much less unlike that of Atlantic North America; the latter, however, largely on account of the operations of man in the rapid conversion of forest into cultivated fields. A. G.

6. *Descriptive Catalogue of the Gallery of Marianne North's Paintings of Plants and their Homes, Royal Gardens, Kew.* Complied by W. BOTTING HEMSLEY, A.L.S. Fourth edition, much enlarged. 1886.—Miss North's noble gift to Kew Gardens is no small addition to the attractions of that great establishment, and its scientific is not less than its popular interest. It consists, besides the accessories, of between 800 and 900 paintings of characteristic and striking plants of the principal extra-European parts of the world, temperate and tropical, made from the life and mostly in their native stations, and generally with some representation of their surroundings. That a delicate lady should have visited so many and such out-of-the-way parts of the world, alone, undergoing various privations, in order to make these paintings, is remarkable; that she should, at her own charges, build an appropriate house for them, arrange them all, as it were, with her own hand, and present the whole to the national establishment which they now adorn, is even more noteworthy. Kew Gardens and the throng of visitors indeed have "reason to be grateful for her fortitude as a traveler, her talent and industry as an artist, and her liberality and public spirit." A. G.

7. *Official Guide to the Museums of Economic Botany, Royal Gardens, Kew.*—Of this we have now the "second edition, revised and augmented," of the No. 1, *Dicotyledons and Gymnosperms*, filling 133 pages, the copious index included. It is so full of interesting matter that the still unpublished part for the *Monocotyledons* is all the more wished for. A. G.

8. *Filippo Parlatore, Flora Italiana*, continuata da TEODORO CARUEL. Vol. VI, *Coralliflorœ*, p. iii.—This concluding part of the sixth volume, carries on the work from the *Scrophulariaceœ* to the *Borraginaceœ*, the latter family and the *Convolvulaceœ* making the principal bulk, although the *Gentianaceœ* are not much inferior in number of species. We note with regret a departure from general and (as we had supposed) settled usage in respect to generic names, namely, in the revival of Tournefortian names which Linnæus had superseded. For example we have *Stramonium* Tourn., instead of *Datura* Linn., *Pervinca* Tourn., instead of *Vinca* Linn. Consequently we have a set of new names, such as *Stramonium leve, S. fœtidum*, etc., in compelete contravention of all the long settled laws of nomenclature. When Linnæus established the binominal system under which Botany has flour-

ished for one hundred and thirty years, he discarded some Tournefortian names for reasons which we should now think insufficient, or, as in the case of *Datura*, he sometimes took up an earlier name. But the names which he then adopted or created were thought to be settled past recall.

The new departure which we deprecate is quite a different thing from the citation of Tournefort as the scientific founder of the genera which Linnæus adopted from him, and himself cites as Tournefortian, in which he is followed by most succeeding botanists, though not with complete regularity. A. G.

9. *Flora Brasiliensis*, fasc. xcvi, 1886, pp. 1–114, tab. 1–24, illustrates the Brazilian *Sterculiaceæ*, and is by Dr. C. SCHUMANN, one of the curators of the Berlin Royal Herbarium. A. G.

10. HOOKER'S *Icones Plantarum*, the fifteenth volume of which was completed last year, is now carried on with new vigor, we believe by means of a legacy of the late Mr. Bentham. The first part of the sixteenth volume appeared in April last, and the first part of the seventeenth followed in May. It is convenient thus to carry on the two volumes simultaneously, because one of them (the seventeenth) is devoted to Ferns, under the hand of the indefatigable Mr. Baker, the other to Phænogams. Among the latter we note with interest, plate 1514, *Asimina insularis*, Hemsley, from Corumel Island, Yucatan. In the brief account of it, no allusion is made to its affinities; so one is uncertain whether the author is aware that it is a close congener of Seemann's *Sapranthus Nicaraguensis*, enumerated in Hemsley's Botany of the Biologia Centrali-Americana. Indeed, it seems to be identical with the plant collected (flowers only) on the island of Nicaragua by Charles Wright, and mentioned in our brief monograph of *Asimina* in the Botanical Gazette for July last. Coming from Nicaragua, we took it for Seemann's species, notwithstanding the much smaller (or much less accrescent) corolla. But the fewer ovules should distinguish it, as well as the difference in size. This *Sapranthus insularis* goes to confirm the genus, which by its equal and similar, thin and plane, and equally accrescent petals, is manifestly distinct from *Asimina*. A. G.

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Solar Heat, Gravitation and Sun Spots, by J. H. Kedzie. 304 pp. 8vo. Chicago, 1886 (S. C. Griggs & Co.)

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SCIENTIFIC INTELLIGENCE.

p. 77, 11 l. from top, for California read Greenland.

Charles D. Walcott,
Office Geological Survey.

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Chas. D. Walcott

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[THIRD SERIES.]

ART. XVIII.—*A Post-Tertiary Elevation of the Sierra Nevada shown by the River beds;* by JOSEPH LECONTE.

[Presented to the National Academy of Science April 24, 1886. Read at Washington, May 3.]

I have on several occasions alluded briefly to the evidences of an elevatory movement in the Sierra at the end of the Tertiary,* but I believe the subject is of sufficient importance to deserve more special treatment. In the present paper I wish not only to give the evidence more fully, but also and especially to correlate this movement with a contemporaneous movement in other parts of the western half of the continent and thus to show that it was very extensive. I wish to show that the upward movement which seems to have affected all high latitude regions at that time, but which was oscillatory and therefore temporary on the eastern side of the continent and in Europe, *on the Pacific side was permanent*, and has largely determined the orographic structure of this side.

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* "Old river-beds of California," this Journ., vol. xix, p. 187, 1884. Science, vol. iv, p. 64, 1884. Compend. of Geology, p. 374. Richthofen in his "Natural System of the Volcanic Rocks," p. 86, speaks of an elevation of the Sierra contemporaneous with the lava flood. In fact, according to him the Sierra region was at that time changed from a gently hilly country to a great mountain range. But his reason for so thinking is the supposed existence of the so-called Blue gravel channel running parallel to the range. This channel is now believed to exist only in the fervid imagination of old miners.

River-beds are most important and accurate indicators of crust-movements. On the *margins* of continents coast lines are our indicators; in the interior, where this fails us, we use river-beds and find them equally valuable. This fact was first distinctly brought out and its importance shown by Powell* and afterwards fully elaborated by Gilbert in his monograph on "Henry Mountains" and by Dutton in his monograph on the "Grand Cañon." It is undoubtedly a most fertile principle and of very wide application in Geology. I give here only a very brief statement of the principle as developed by these geologists in order that its application to different regions and especially to the case in hand may be more readily followed.

A river seeks ever to find its *base-level*, i. e., the level at which the tendencies to the opposite processes of erosion and sedimentation balance each other. When this is reached the river neither cuts nor builds up. Suppose then, that a river in its lower course, has reached or nearly reached its base-level. If now the land rises the river immediately begins to cut its bed to lower and lower level until it again reaches its base-level. If on the contrary the land sinks the river will build up by sedimentation until it again finds the level of equilibrium. In the Plateau region, for example, we have the singular phenomenon of a river system running far below the general level of the country; in Holland, on the contrary, we have the converse condition of a river system running above the general level of the country:—in the one case below the feet, in the other above the heads of the people. But both cases come under the same general principle of rivers seeking their base-level. In the one case they seek it by erosion, because the country is rising; in the other by sedimentation, because the country is sinking.

But the above statement requires some modification. In a steady crust a stream never *completely* reaches its base-level in any part because the base-level is constantly changing. The position of the base-level of a stream is determined by the relation of the velocity of the current to the freight of sediment† and the freight of sediment depends on the slope of the upper tributaries. These upper tributaries are always above their base-levels and therefore always cutting and lowering their slopes. But the lowering of the slopes of the upper parts diminishes the freight of sediments and therefore lowers the base-

---

* Exploration of the Colorado River, p. 203 and seq.

† In a river bearing sediment, the current-energy is consumed partly in carrying and partly in eroding. As the quantity of sediment increases, more and more of the current energy is consumed in carrrying and less and less is left over for erosion, until finally all is thus consumed and the river begins to build by deposit. Thus flooded rivers with rapid current will often build up by deposit, because overloaded, and then afterwards, even with much less current will again scour out their channels.

level of the lower parts of the stream, which therefore also renews its cutting. Thus, as already stated, in a steady crust, even the lower part of a stream never completely reaches its base level, for this is ever being lowered by the lowering of the beds of the upper parts. The only complete limit to erosion—the only final and absolute base-level is, of course, the sea level. But although a river never completely reaches its base-level until it reaches the sea level; yet in a steady crust, it so nearly reaches it in its lower parts that for our purposes we may regard this level as being often practically reached.

Suppose then a country to be raised and then to remain steady. In such case as already explained the streams will cut until in their lower parts they reach or nearly reach their base-level. Now they cut no longer or only at extremely slow rate. As soon as the down-cutting ceases, the stream begins to sweep from side to side under-cutting its banks and widening its channel. But meanwhile the valley slopes on either side and the separating divides are being worn down lower and lower by rain-erosion or weathering. Thus in a country which has remained steady for a long time the topography consists of wide trough-like river-beds separated by low rounded divides. On the contrary, in a country rising or recently risen we have deep, narrow cañons and high, sharp divides, or else high table-lands, between. Therefore deep, narrow cañons are evidence of recent and rapid rising; the *deeper* the cañon the more *rapid* has been the rising. But since the widening is meanwhile also progressing, the *narrower* the cañons, the more *recent* has been the rising.

We have seen that the more rapid the rising, the more rapid the cutting; also that after a while if the crust remains steady, the cutting ceases and the divides are lowered. It follows therefore that the depth of river cañons cannot be taken as a measure, even a rough measure, of time; (1) because the rate of cutting is so greatly dependent on the difference between the actual river-bed and the base-level, and (2), because when the deepening ceases the lowering of the divides still continues and the cañons are thenceforward lessening in depth. Therefore so far from deep cañons being evidence of geologically long work, the very reverse is true, viz: wide, shallow river-beds are characteristic of old topography.

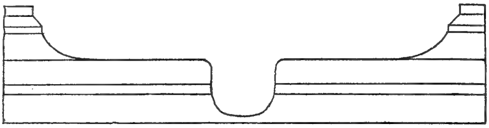
Again: we have seen that if a country rises and then remains steady the rivers will cut to base-level and stop cutting—the channels will stop deepening and will only widen. If now another rise commences the rivers will cut again, making an inner and narrower gorge. Thus successive risings may be recorded in successive benches more or less marked.

Application of these Principles.

1. *Plateau Region.*

This remarkable region, as is well known, is intersected by profound cañons which are among the wonders of the world. The reason is, that it has been rising in comparatively recent times and faster than the rivers could cut. But that the rising has not been continuous and at uniform rate, is proved by the structure of the Grand Cañon as shown in the figure (fig. 1).

1.



Ideal section across Grand Cañon. After Dutton.

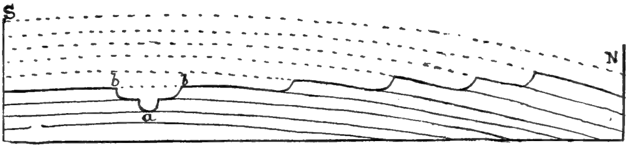
It consists, as seen, of two cañons, one within the other. The outer cañon is 5–6 miles wide, the inner only about $\frac{3}{4}$ of a mile wide, or about as wide as deep. This inner gorge is much the more recent and therefore has not yet had time to widen out.

The history of the plateau region, as recorded in the Grand Cañon according to Dutton, is as follows: At the end of the Eocene this region was first laid bare by the draining of the great Eocene lakes, and the present river system was established. During the whole Miocene there was a continual arching of the earth-crust in the region, with consequent rising of the country and proportionate erosion over the whole area. This however is recorded rather in the erosion cliffs which characterize this region, than in the cañons proper. At the beginning of the Pliocene a more rapid rising commenced and the outer cañon began to form and continued to deepen as the land rose. Then the rise ceasing the river gradually reached its base level, the cañon ceased to deepen but continued to widen until the outer cañon reached nearly its present condition. Then later, viz: at the beginning of the Quaternary, the land began again to rise, and the river again to cut rapidly and has since that time cut the inner gorge. It is probable that the rising, and certain that the deepening, still continues.

Outside of the Grand Cañon northward there is a succession of regular tables 10–20 miles wide, terminated by irregular E. and W. cliffs 1000–2000 feet high (fig. 2). All these cliffs are now receding by erosion. If the arching strata be restored the amount of erosion is seen to be enormous. According to Powell the average thickness removed on the whole area is 6000–8000 feet, and the extreme thickness on the highest part

10,000–12,000. Besides this, the Grand Cañon is itself 6000 feet deep, making an extreme erosion of 18,000 feet; and taking the bottom of the Grand Cañon at 2000 feet above sea-level, it makes the whole rise during the Tertiary (for this whole region was sea-bottom during the Cretaceous) at least 20,000 feet. The outer cañon walls *b b* may be regarded as commencing cliffs, or the successive cliffs as far-receded and therefore very old cañon walls: although the forms are certainly unique in this case. The exceptional verticality of the widening cañon-walls is the result partly of the very gentle outward dipping of the strata composed of alternate hard and soft material, and partly of the air and climate, and the absence of vegetation to hold the soil and humus to decompose the rocks.

2.

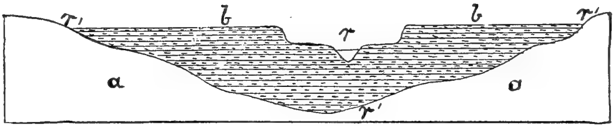


Ideal section across the Grand Cañon, showing the successive erosion-cliffs to the northward. The dotted lines show the amount of erosion.

2. *Rivers of the eastern drift region.*

Over the whole area of the drift region in the eastern part of the continent we have, as is well known, the reverse condition of things. The rivers there have sought their base-level by sedimentation instead of erosion, because the land has subsided from a previous more elevated condition. Beneath the present river-beds in all this region we find much deeper and wider beds, now filled with drift or with old river deposits, as shown in the ideal section, fig. 3. In this figure the wide river bed r' r' r' is the tertiary and r the present river bed. This relation between the old and present river beds shows that in later Tertiary and early Quaternary times the land was higher than now, and the rivers cut to their base-level; and that this state continued a long time until the channels had

3.

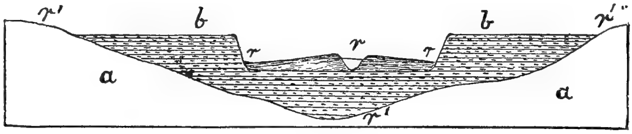


Ideal section across a river bed in Drift region. r, Present river bed; r' r', old river bed; a, country rock; b b, old river sediment.

widened out. Then during the later Quaternary (Champlain epoch of Dana) the land subsided and the rivers seeking their base-level by deposit filled up the old channels to their brims. Then lastly during the transition to the present (Terrace epoch) the land rose again and the rivers began again to cut; but the late Tertiary elevation has not yet been reached by the land nor the old beds by the rivers.

In the case of the Mississippi river we find as I think the record of still another movement in the opposite direction, i. e. subsidence, in still more recent times. This is shown by the upbuilding again of the river-bed by deposit of recent alluvium to an average depth, according to Hilgard, of 50 feet. Fig. 4 is an ideal section across the Mississippi showing these facts. After what we have said the record of this river is easily read.

4.



Ideal section across the Mississippi river and bluffs. r r, Present river bed; r' r' r', old river bed; a, country rock; b b, old river sediment.

1. The old bed r' r' r', 100 miles across, was formed during a more elevated condition of the land in late Tertiary and early Quaternary (Glacial) times. 2. In later Quaternary (Champlain) this was filled to the brim with deposit 400 or more feet thick, because the land was then subsided and probably also because of more abundant sediment. 3. During the Terrace epoch the land rose and the river cut until the present wide channel r r, 10 miles wide and bounded by bluffs 200 feet high, was formed. This wide channel is not the result, however, of ordinary cliff recession as in the case of the Grand Cañon, for there has been neither time enough to produce such width nor suitable material to develop by recession such perpendicular forms; but it is due to the shifting of the great river from side to side and undercutting the bounding bluffs. 4. Lastly, during the present epoch there has been some subsidence again and a refilling to the extent of 50 feet by the alluvium. Other evidences of this last subsidence are found in old buried forest grounds in the delta, far below the present sea-level.

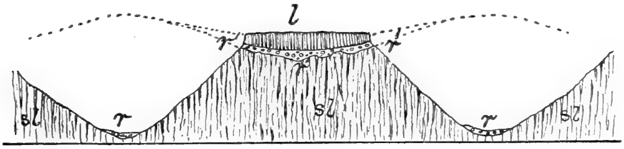
The phenomena of European river-beds are substantially similar to those of eastern North America in the drift-region.

River-beds of California and the evidences of Sierra-Elevation.

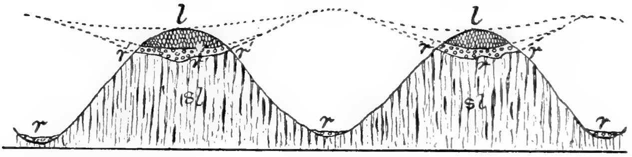
All that I have thus far said is introductory to this the main subject. It is well known since the publication of Whitney's

Geological Survey, that there is a peculiar, almost unique relation of the old to the new river-beds in middle California. At the end of the Tertiary period the then existing river-system was obliterated by an immense flood of lava which, issuing from fissures in the high Sierra, flowed westward down the river-valleys filling them completely and displacing the rivers. The displaced rivers, of course, immediately set to work cutting new channels mainly on the intervals or low divides between the old channels, because there the lava was thinnest or absent altogether. Since that time the rivers have cut beds 2000 to 3000 feet *below the level of the old beds.* The relation between the old and new beds is shown in the figures (figs. 5 and 6) in which *r′ r′* represents the old Tertiary beds and *r r* the present beds. Sometimes the lava is hard basalt and erosion then gives rise to table-mountain forms as in fig. 5. Sometimes it is softer, as ash, tufa, etc., and thus erosion-forms are rounded as in fig. 6.

5.



6.

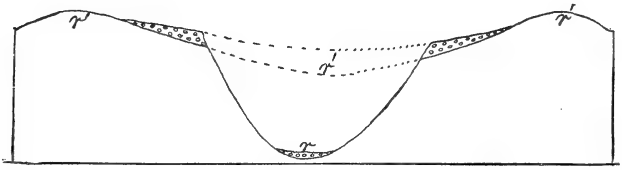


Ideal sections across river beds in middle California. In fig. 5 the lava is basalt, in fig. 6 tufa. *r*, Present river bed; *r′ r′*, old river bed; *l*, lava; *sl*, slate.

Now what we wish to emphasize, is that the lower position of the present river beds is not the result of longer time of cutting (for the time has been very much shorter), but of more rapid work—that this position is demonstrative proof that a very great increase in the height and angle of slope of the Sierra took place contemporaneously with the lava flow at the end of the Tertiary or beginning of the Quaternary. The old river-beds were probably established at the beginning of the Cretaceous when the Sierra range was born from the sea, and were being cut and shaped throughout the whole Cretaceous and Tertiary. By the end of that time they seem to have been broad, shallow troughs with low divides between as shown by the dotted lines in figs. 5 and 6. The rivers seem to have reached their base-level and had ceased to deepen their channels, but rain-erosion still continued to widen the valleys and cut down the divides. The river-system had therefore assumed the form characteristic of old topography. Then came the lava flood displacing the rivers, and the contemporaneous elevation changing the base-level and enormously increasing the erosive power of the rivers. These therefore without loss of time, commenced cutting anew and in comparatively short time have cut far lower than before. And because they have worked rapidly and are still working, the cañons are deep V-shaped. The Tertiary rivers were working during the whole Cretaceous and Tertiary; the present rivers only during the Quaternary and present. The working time of the former was many times greater than that of the latter; and yet the present rivers have cut much deeper. It is impossible to explain this except by supposing a great rise, probably several thousands of feet with increased slope of the range, at the end of the Tertiary.

This Post-tertiary elevation of the Sierra extended far beyond the limits of the lava-flood. The lava-flood was a concomitant, possibly a result, not the *cause* of the elevation. In Southern California beyond the limits of the lava-flood we have equally convincing evidence of great elevation at this time. Here the rivers were not displaced—they continued to occupy the same places, but commenced to cut deeper at that time. The evidence of this is found in the fact that remnants of the old river-gravels are now found clinging high up on the slopes of the present cañon-sides. The relation of the old to the new river beds in Southern California is shown in the ideal section, fig. 7, in which the letters indicate the same as in previous figs. I first observed this during the summer of 1883 in Lytle Creek Cañon where the old gravels high up on the sides of the present cañon-walls have been worked for gold with indifferent success in several places. I visited and examined them carefully. I have heard of a similar relation in other places but have not examined them. There can be no doubt therefore that the elevation extended the whole length of the Sierra. The maximum was probably in the region of the

7.



Ideal section across a river bed in Southern California. r, Present river bed; r' r', old river bed.

highest summits and deepest cañons, viz: about the head waters of the King and Kern rivers.

The relation of the Tertiary to the present river-beds is unique only in *middle* California, because there the lava-flow was sufficient only to fill up the valleys, not to cover deeply the divides. On these divides therefore the rivers located their new channels. Farther north the lava-flood was so deep and universal that either the rivers have not been able to cut through, or if they have, there is no definite relation of these channels to the old channels. Farther south the lava did not extend and the rivers were not displaced.

Contemporaneous Movement in the Plateau and Basin Regions.

We have already seen, p. 170, that the inner gorge of the Grand Cañon was formed by a second elevation of the Plateau region, and that according to Dutton, this movement took place at the end of the Tertiary. It is almost certain then, that it was correlated with the Post-tertiary elevation above insisted on. The new river-cañons of mid-California, the deeper portions of the cañons of Southern California, and the inner gorge of the Grand Cañon are contemporaneous and produced by the same general movement. The movement in the Sierra was accompanied by a prodigious outflow of lava. In the Plateau region it was attended by the formation of a system of N. and S. fissures several hundred miles long, breaking the crust of the earth into huge oblong blocks which, settling unequally, have given rise to those wonderful N. and S. *displacement*-cliffs which equally with the E. and W. *erosion*-cliffs (p. 170), are a characteristic feature of the region. It was attended here also with outflows of lava, but on a lesser scale than in California. It was attended also with a readjustment, if not the formation, of the great fissures and faults of the Basin region. In connection with the elevation of the Sierra, the great fault-scarp on the east side of the Sierra was doubtless increased. The same is true of the fault-scarp on the west side of the Wasatch range. The elevation therefore was not only general over the whole region, but also local, i. e. greater along these ranges.

Contemporaneous movements in Southern Oregon.

The Basin region, as long ago shown by Gilbert and Howell*, is affected by a system of N. and S. fissures breaking the crust of the earth into oblong blocks, which in settling have been mostly tilted so as to give rise to a series of monoclinal N. and S. ridges. This is well shown in the following fig. (fig. 8) taken from Howell. We have already said these were pro-

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* Wheeler Survey, vol. iii.

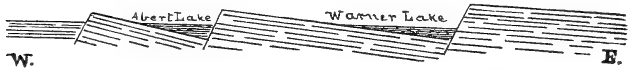
duced at the beginning of the Quaternary—we now proceed to give further evidence.

Mr. Russell, in a recent very excellent and suggestive paper on Southern Oregon,* has shown that the country rock of this region consists wholly of successive sheets of lava several thousand feet thick, originally level, but now broken by N. and S. fissures into oblong blocks, which are mostly tilted in such wise as to produce a series of faults, the uplifted sides forming ridges while on the downthrows have accumulated *lakes.* This is shown in fig. 9. In all cases the faults are normal, and therefore when the fissures dip in opposite directions, the wedge-shaped blocks thus produced may drop bodily down, or be raised bodily up, as shown in fig. 10, according as the base of the wedge is upward or downward. We have in this region therefore, on a smaller scale but in very simple and perfect condition, the characteristic Basin structure, except that only in this case the country being in the region of the great lava-flood, the broken and displaced layers are lava-sheets instead of sediments. As to the age of these faults, although he acknowledges some discrepancy in the evidence derived from vertebrate and invertebrate fossils, Mr. Russell decides with great positiveness that the old or enlarged lakes of which the present lakes are the residues belong to the same period as Lake Lahontan and Lake Bonneville, i. e. to the Quaternary. The fissures were therefore formed and the displacements commenced at the beginning of the Quaternary, doubtless by the same orographic movement which so greatly increased the elevation of the Sierra.

8.

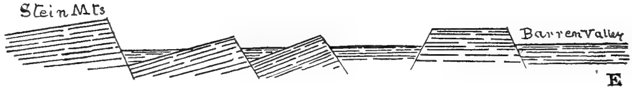
Section showing Basin region structure. After Howell.

9.



Sketch sections across Warner valley. After Russell.

10.



Sketch section across Stein Mts. After Russell.

I have referred above to the supposed discrepancy between

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* U. S. Geol. Rep., 1882–'83, p. 435.

the evidences of the age of the enlarged lakes as derived from the vertebrate and the invertebrate remains in the lake deposits. The latter are the same as those of L. Lahontan and are all living now in rivers of California. The former are the mammoth, camels, gigantic edentates, horse, etc., and are referred by Marsh to the Equus beds of the uppermost Pliocene. These vertebrate remains are all on the surface and underlaid by the recent shells, and Mr. Russell thinks they may have been drifted in from older, i. e. Pliocene deposits; for the testimony of the invertebrates (shells) seems conclusive. But in any case the mammoth, the gigantic edentates and the modern horse are placed by nearly all authorities in the Quaternary. If we reject Quaternary as a distinct period, and have only Tertiary and Recent, these animals may well be put in the uppermost Pliocene instead of the Recent. But if we are to have a Quaternary or transition between the Tertiary and the Recent, then all these animals more properly belong to the Quaternary.

Relation of the Post-Tertiary movement to the Great Lava-flood.

The great Lava-flood of the Northwest, which covers an area of 200,000 square miles, and where cut through by the Columbia river, at the Cascade, is between 3,000 and 4,000 feet thick, probably *commenced* to be outpoured at the beginning of the Pliocene epoch.* The evidence of this is not entirely conclusive. All we know for certain is that it is immediately underlaid by, and was therefore outpoured upon, eroded strata of Miocene age. It is almost certainly, therefore, Post-miocene. But the fact that great orographic movements over the whole western half of the continent occurred at the end of the Miocene (viz: the increased elevation of the Plateau region and the cutting of the outer Grand Cañon, and the letting down of the Basin region on the one side and the Plains region on the other, with the great increase of the size of the lakes in these regions; and especially the formation of the coast ranges of Pacific coast), makes it very probable that the great lava-flood was associated with these movements and commenced at the same time. But if so, it probably continued by successive fissure eruptions through the whole Pliocene, and by volcanic eruption almost to the present time. Certainly the great flows of California were as late as the end of the Pliocene.†

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* "Great Lava-flood of the Northwest," etc., this Journal, vol. vii, p. 177, 1874. Mr. Russell in his paper on Southern Oregon, p. 451, quotes me as referring the lava-flood to the Miocene. The *underlying strata* are Miocene. The lava is probably Pliocene.

† Mr. Ross Browne of the University of California, from very careful survey of one of the old river beds of California finds evidence of several lava-flows, one above another separated by gravels, but the greatest, and that which displaced the river, was the latest.

Relation of the Post-Tertiary movement to the great fissures and normal faults of the West.

In the Basin region, Mr. Russell and others have drawn attention to the entire distinctness in time and in character, of the forces which crumpled the strata (mountain-making forces) and those which produced the fractures and faults, and therefore which determined largely the present orographic structure; the latter being much more recent. The former took place at the end of the Jurassic, the latter probably at the end of the Tertiary. So also in the Sierra range, we must distinguish betwixt the orogenic forces which crumpled the Carboniferous, Triassic and Jurassic strata lying on its flanks and that much later movement which greatly increased its height and determined its present slopes and which caused the rivers to cut the present cañons so deep. The former, as Whitney has shown, took place at the end of the Jurassic, the latter as we have seen, at the end of the Tertiary. The Sierra as we now know it, both in height and in scenic configuration, is largely due to this latter movement.

Furthermore, it seems probable, nay, almost certain, that those great fissures which break the crust of the earth into blocks which by unequal settling give rise to normal faults, were produced not at the time of orogenic crumpling, but subsequently. Mountain ranges are in the first instance formed by horizontal pressure crumpling and upswelling thick sediments on marginal sea-bottoms;[*] but these sediments being comparatively soft, yield easily, and may be mashed together with little fracturing; or if there be fractures, these give rise to *reverse* faults, i. e. a pushing of the hanging wall over the foot wall, the extreme forms of which are the over-thrusts and horizontal shearings described by Geikie and Peach in the Scottish highlands.[†] But after the crust has again become rigid, bodily movements of a somewhat different kind, and the cause of which we still very imperfectly understand, give rise to fractures which by *gravitative settling* produce *normal* faults so common everywhere. It is certain that the great normal faults which characterize the Basin region, among which must be counted the Eastern Sierra fault and the Western Wasatch fault, were produced in this way long after the orogenic crumpling had ceased. It is certain, also, that the prodigious faults which characterize the Plateau region, where there was no orogenic crumpling at all, were formed in the same way. Is it not probable then that the fissures of the Sierra also, which by filling with mineral matter have formed its metalliferous veins,

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[*] Theory of formation of great features of Earth Surface, this Jour., vol. iv, p. 345 and p. 460, 1872.

[†] Nature, vol. xxxi, p. 29, 1884.

were formed not at the time of the birth of this range, but rather during its growth in the Cretaceous, Tertiary, and even at the end of the Tertiary?

Evidences of still more recent movements.

All the fault-movements spoken of above have been going on apparently even to the present time. We have abundant evidence of this in the great Wasatch fault as shown by Gilbert* and in the faults of the Basin region and especially of Southern Oregon as shown by Russell.† With every readjustment and increase of fault there is probably an earthquake. The great fault on the eastern side of the Sierra and therefore the elevation of the crest of this range has increased in very recent times and is still increasing. The great Inyo earthquake of 1872 was certainly accompanied and probably *caused* by a notable (25 ft.) increase of this slip along a distance of 40 miles.‡ This is by far the most probable cause of most earthquakes. We may conceive forces, of the nature of which we know little, elevating slowly one side of a fissure, usually a mountain range, and the other side dragged up also by adhesion, a little way, say 10 to 20 feet, until finally the lower side drops and produces an earthquake. If then the Sierra is still rising, the rivers must be still cutting. The shape of the cañon confirms this conclusion.

Observe, then, that the Post-tertiary rise of the Sierra was not a continental movement merely (for this would not have increased so greatly the slope); nor was it orogenic crumpling and up-swelling; but it was elevation of the crest with large increase of the eastern fault-scarp. It is impossible to overlook the connection of this great increase in the height of the Sierra with the progressive desiccation of the Basin region which commenced at this time.

Contemporaneous Elevation of the west side of South America and subsidence of the mid-Pacific bottom.

We have thus far spoken only of elevatory movements on the west side of the *North* American continent; but a similar movement seems to have occurred at the same time and on a still grander scale on the west side of the South American continent also. This is shown by the well known beach lines traced by Darwin up to 1200–1500 feet above present sea level, and

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* History of L. Bonneville, Report of U. S. Geol. Surv. for 1880–81, p. 170.

† History of L. Lahontan, Report of U. S. Geol. Survey, 1881–82, p. 195, and Reconnaisance of Southern Oregon, Report of U. S. Geol. Survey, 1882–83, p. 435.

‡ Several writers have lately spoken of the readjustment of this fault as the cause of the Inyo earthquake. I believe that the first mention of this was in my article on Origin and Structure of Mountains, this Journal, vol. xvi, p. 101, 1878.

still later by recent corals found by Alex. Agassiz 2900 feet above the same level.* It is evident then that the whole western side of the two Americas participated in this upward movement. Now so great and extensive an elevation must have had its correlative in corresponding subsidence somewhere. Where shall we look for it unless in the Pacific bottom? The observations of Darwin and Dana on the phenomena of Coral reefs have long been regarded as demonstrative proofs of such a subsidence over an immense area (at least 10,000,000 square miles) in mid-Pacific. It is true that the "Subsidence theory" of the origin of barrier reefs and atolls has very recently been seriously questioned by Mr. Murray† and others, but it must still be regarded as the probable explanation. Barriers may certainly and atolls possibly be formed without subsidence, but subsidence is probably the most common cause.‡ The fact of the recent continental elevation on the Pacific side of the two Americas is additional presumption in its favor. If so, then, it is probable that the down-sinking of mid-Pacific floor, the elevation of the whole western side of the two Americas, the prodigious erosion and cañon-cutting of the Plateau region, the deep V-shaped cañons of the Sierra and the great N. and S. fissures and normal faults of the Basin and Plateau regions are all closely related to each other. Moreover the movements which determined these phenomena were all in progress from the beginning of the Tertiary, reached their greatest intensity in early Quaternary and are still progressing.

Cause of these movements.

In these latter times there has been a tendency to regard elevation and subsidence when unattended with plication, as a simple matter of equilibrium of a floating crust. According to this view, wherever abundant sedimentation is going on, there the crust weighted down by the increasing mass subsides *pari passu*, and wherever erosion is exceptionally active as in great mountains and high plateaus, there the ever lightening crust rises *pari passu*. Thus subsidence and elevation are caused by weighting and lightening.§ Doubtless this is a real cause which must not be neglected, but it cannot be the principal cause. Doubtless the proposition is true, but the converse proposition is much more true, viz: that subsidence is the cause and necessary condition of sedimentation, and elevation the cause of exceptional erosion. The plateau region, for exam-

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* Proc. Am. Acad. Sci., xi, p. 257, 1876.

† Nature, vol. xxii, p. 251, 1880, and vol. xxxiii, p. 202, 1885.

‡ Dana, this Journal, vol. xxx, p. 89 and 169, 1885.

§ Nature, vol. xxvii, p. 523; vol. xxviii, pp. 323, 365, 388, 488–539, 587; vol. xxix, p. 212. Geol. Magazine, vol. x, pp. 302 and 348, 1883.

ple, during the Carboniferous, Permian and whole Mesozoic times was a region of subsidence to the extent of 15,000 feet* (for such is the thickness of these strata there). Since that time it has been a region of elevation and has risen probably at least 20,000 feet. But the extreme *general* erosion (i. e. leaving out the cañon-cutting) has been only about 12,000 feet, leaving the region still 8000 feet high in its highest parts. Now first, why did the rise commence at all? and 2d, how can a lightening by removal of 12,000 feet cause an elevation of 20,000 feet? In fact at every step the erosion has lagged behind the elevation, as it ought, if it be effect. The fundamental cause of subsidence and elevation over great areas must therefore be sought elsewhere, although doubtless weighting and lightening, by adding to the force or lessening resistance, will cause these movements to go farther than they otherwise would. This is but an example of reaction of effect on cause, of which we find so many in all cases of complexly related phenomena. As to the real and fundamental cause of the oscillatory crust-movements we are not yet prepared to speak with any certainty. We must wait for more light.

ART. XIX.—*The Strain-effect of Sudden Cooling as Exhibited by Glass and by Steel;* Second Paper;† by C. BARUS and V. STROUHAL.

IN our last paper‡ we compared the strains experienced by glass and by steel on sudden cooling, by aid of the density variations observed when the bodies carrying strain were annealed, *as a whole.* In this paper we desire to substantiate and to give sharper expression to our earlier inferences relative to the temper-strain in glass. To do this we repeat Professor Rood's experiments on the polariscopic effect of continuous annealing of cooled glass, at low temperatures. Our second purpose in this paper is to investigate the density relations of consecutive similar shells of the Prince Rupert drop, and the optical character of the successive cores. Availing ourselves of all the evidence adduced in our investigation at its present stage, we endeavor in general to show that the optical effect of the temper-strain in glass may be regarded as the analogon of the electrical effect of the temper-strain in steel.

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* Powell, 2d Report of U. S. Geol. Survey, Introduction, p. xv.

† Communicated with the permission of the Director of the Geological Survey.

‡ This Journal, III, xxxi, p. 439, 1886.

Certain general properties of the Prince Rupert drop.

It is well known that mere breakage of the tail of a P. R. drop is sufficient to shatter it; that the splinters fly apart with explosive violence. It is not so well if at all known, that the same drop may be dissolved in hydrofluoric acid to a mere spicule without exploding. This peculiar behavior calls to mind certain properties of nitroglycerin, inasmuch as this substance may be burned off quietly in a wick, but explodes on percussion. It is in keeping, moreover, with a friend's[*] ingenious suggestion that in the quenched globule we may possibly encounter a polymerization of the molecular structure of the annealed globule. The fact that the strain in question is of an ordinary mechanical kind seems proven, however, by the observations of Table I, in which the behavior of P. R. drops from which different thicknesses of shell have been removed by solution, is described. Diameter refers to the mean transverse thickness of the drops; ϑ and μ to the thickness and the mass, respectively, of the dissolved shells. After removing a sufficient depth of shell, the residual explosive properties were tested either by crushing the reduced drop, longitudinally, in a vise, or by striking in the same direction with a hammer.

TABLE I.—*Explosive tendency of P. R. Drops.*

No.	Minutes in HF.	Diameter.	ϑ	μ	Remarks.
		cm	cm	g	
12	0 5	0·848 0·835	0·006	----	Shattered on breaking base of tail. Explosive tendency diminished in marked degree.
10	0 10	0·796 0·766	0·015	----	Shattered on being split longitudinally. Fragments partially cohere.
11	0 14	0·795 0·760	0·017	----	Shattered on being split longitudinally. Fragments partially cohere.
13	0 30	0·774 0·712	0·031	0·291	Shattered on being split longitudinally. Fragments more cohering.
3	0 --	0·795 0·688	0·054	0·492	Is not shattered on splitting. Conchoidal fracture.
5	0 --	0·825 0·720	0·053	0·491	Is not shattered on splitting. Conchoidal fracture.
7	0 --	0·763 0·539	0·112	0·722	Is not shattered on splitting. Conchoidal fracture.
8	0 --	0·791 0·557	0·117	0·752	Is not shattered on splitting. Conchoidal fracture.

The Table shows that the explosive tendency of the P. R. drop becomes rapidly less pronounced as the thickness of removed shell increases; that this tendency is very perceptibly

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[*] A precautionary suggestion for which we are indebted to Dr. Gooch.

impaired by the removal of less than one-tenth millimeter of shell; that it vanishes almost wholly with the removal of one-half millimeter of shell. If the radius of the drop be diminished about $0{\cdot}03^{\mathrm{cm}}$ the particles of the fractured globule frequently cohere, and the original structure may then be inferred from the general direction and distribution of the fissures. The arrangement of the individual fragments is quite characteristic; they are found to be flat irregular conoids, with their apices toward the line of symmetry of the drop, their bases in its surface,—an arrangement something like the eye of an insect, or even more like the fruit cone of a spruce tree. In other words the radial structure of the fissured P. R. drop is distinctly marked. This proves that the original (unbroken) drop must have possessed a box-within-box structure; that if the bubbles were symmetrically disposed, particles similarly situated with reference to the line of symmetry would be in like states of strain. But the law according to which matter is distributed from circumference to axis cannot be inferred, since the stated phenomena follow equally well both for surface dilatation and for surface compression.

All the P. R. drops examined were found to scratch ordinary glass with facility; but on taking the strain out of the drops by annealing them at white heat and slow cooling, their hardness did not materially change. The observed hardness was therefore a property of the glass itself. Indeed by rubbing together a quenched and an annealed P. R. drop a difference of hardness could not be discerned with certainty.

Polariscopic Observations.

Annealing.—Our object in this place is merely to detect variation in the polarization figure, produced either by removal of shells or by annealing. It is therefore sufficient to examine the drops in a given fixed position between polarizing plates.* Disturbances due to diffuse refraction are satisfactorily eliminable by submerging the P. R. drop in glycerin, the refractive index of which is nearly that of the glass. The demarcation is then distinct and the colors clear, so that the figures can be drawn. The necessity of grinding special plates is thus fortunately obviated; applied to a quenched P. R. drop the operation would not, of course, be feasible.

In the case of simple annealing, variations of the polarization figure are due to a diminution of what we may call the birefractive power of the P. R. drop. In the case of removal of shells, variations of the figure result from diminution of

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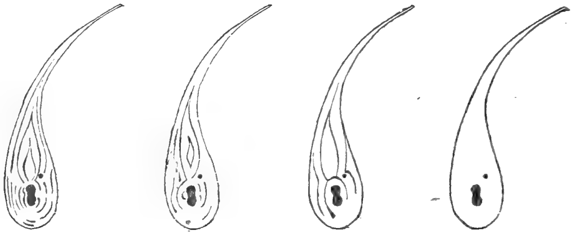
* We are indebted to Professor Baird for the use of a simple but efficient reflecting polariscope, formerly the property of Professor Henry.

thickness possibly associated with diminution of birefractive power. The solution of the drop in hydro-fluoric acid does not materially interfere with its transparency.

Our polariscopic experiments were made with the P. R. drops, Nos. 1, 2, 4, 6 and Nos. 3, 5, 7, 8, 9. The first four of these were simply annealed; the remainder examined after consecutive removals of shells. It is expedient to describe the experiments with annealed globules first. These experiments are so striking and so easily repeated on the one hand, and so difficult to reproduce accurately in a drawing on the other, that the following very careful freehand sketches of the main features of the figures are here inserted principally for purposes of record. The figures represent P. R. drop No. 6, in a fixed position between parallel nicols.



On annealing as far as $T=200°$, variations of figure are not certainly perceptible. After very long annealing at this temperature (200°), an influence appears, but is restricted to changes of color. It is particularly to be observed, that the position and contours of the original polarization figure shows an obvious relation to the position of the included bubbles (black spots in figure). This was the invariable result for all the P. R. drops examined. It is in accord with our inference of "centrifugal" contraction* discussed elsewhere. At 200° therefore, so far as these special manifestations are concerned, change of strain in glass is incipient. The P. R. drop, if broken, is still explosive; though perceptibly less so, than the original drop. After one hour of annealing in boiling mercury (360°), the changes of the polarization figure are obvious. The whole appearance is more diffuse, the colors bolder and broader and the demarcation less distinct and delicate. These striking observations can only partially be reproduced in a figure. We have encountered very marked diminution of birefractive power, after seven hours of annealing in boiling mercury, the evidences of diminished birefractive power having visibly accrued. The figure as a whole is simpler, the coloration more gross.

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* L. c., p. 450.

Finally, after annealing in boiling sulphur (450°), the polarization figure has wholly vanished. We have in hand a hollow globule free from æolotropic strain. We show below that the substance of the quenched P. R. drop is under a strain of dilatation. It is necessary to bear in mind that the isotropic part of this strain is not demonstrable by optic means. The drop annealed at 450° has, however, wholly lost its explosive character.

Here therefore we encounter the first important analogy between the optical behavior of quenched glass and the electrical behavior of quenched steel. Change of strain in glass is incipient at 200°; in steel at 50°. Change of strain in glass is complete at a temperature certainly greater than 350° and less than 450°. The corresponding limit for steel cannot be so well defined.* In both cases the essential dependence of the result to be reached upon the temperature and the time of annealing (asymptotic relations) is the marked feature of the phenomenon.

Solution.—In Bulletin U. S. G. S., No. 35, we communicate a series of results on the resistance of consecutive conaxial layers of steel rods. From these we select the following digest, Table II. Having secured the rods (fine grained steel, quenched hard, length 6^{cm}, diam. $0{\cdot}6^{cm}$) in an especial clamp, the resistances between points about 5^{cm} apart were measured by a modification of Matthiessen and Hockin's method. A process of galvanic solution enabled us to remove given thicknesses of shell consecutively. After each of these removals resistance measurements were made. In the table W_t denotes the effective resistance in microhms, S_0 the corresponding specific resistance referred to the cubic centimeter; R, ϑ the mean radius and thickness, respectively, of the consecutive shells, s_0 their (calculated) specific resistance.

It is difficult to arrive at accurate values for specific resistance in these measurements; for we encounter very small values for total resistance (W_t) at the inception of the experiments, and small and irregular values of sectional area at the close. Inasmuch as sections are always measured too large, the values for specific resistance (S_0) are too large, and the error increases rapidly as we pass from greater to smaller diameters. The mean error of S_0 is certainly several per cent and hence s_0 is only an approximation. Nevertheless these results are important; they show that in case of hard rods less than $0{\cdot}6^{cm}$ thick, the values of resistance taken from circumference to axis

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* "It is remarkable and significant that the electrical effects due to the annealing of a glass-hard steel rod vanish almost entirely. . . . . at a temperature at which the density of a homogeneous hot rod is the same as the density of an (otherwise) identical cold glass-hard rod.—*Bull.* 14, 97.

TABLE II.—*Resistance of consecutive cores and shells of hard steel rods.*

Rod No.	Shell or Core No.	W_t	S_0	R	ϑ	s_0
11	0	660	41·4	----	----	--
	1	820	44·1	0·31	0·024	31
	2	1000	44·0	·28	32	46
	3	1290	43·2	·24	35	45
	4	2250	43·3	·20	60	43
	5	4130	46·3	·15	37	39
	6	6620	46·6	·12	27	46
	7	16040	52·8	·09	33	42
12	0	680	41·8	----	----	--
	1	820	42·6	0·31	0·021	37
	2	1020	42·7	·28	34	43
	3	1300	44·3	·25	27	37
	4	2440	46·0	·21	54	42
	5	3390	45·7	·16	34	47
	6	5400	44·4	·13	34	47
	7	10730	57·4	·10	26	34
	8	22640	50·8	·07	29	49
13	0	660	40·4	----	----	--
	1	730	42·0	0·31	0·014	30
	2	800	42·4	·30	16	38
	3	910	43·0	·28	20	39
	4	1310	43·7	·24	44	41
	5	2110	44·0	·20	44	43
	6	3200	45·8	·16	30	41
	7	8330	47·0	·12	57	45
14	0	680	41·4	----	----	--
	1	740	42·0	0·31	0·013	36
	2	1090	54·8	----	----	--
	3	960	42·7	·29	·035	39
	4	1360	41·9	·25	42	45
	5	1990	44·7	·21	38	36
	6	2930	47·0	·17	31	40
	7	5710	42·9	·13	52	51
	8	21280	53·9	·08	44	39

along any radius do not perceptibly diminish. It was this curious result, apparently adverse to the hypothesis of strain, which induced us to examine the corresponding behavior of quenched glass.

The diameters 2ρ of P. R. drops, Nos. 3, 5, were successively reduced* as follows:

$2\rho =$ 0·79 0·75 0·72 0·69 0·62 0·56 cm.,
and $2\rho =$ 0·82 0·79 0·75 0·72 0·65 0·59 cm.

The polarization figure, drawn after each of these reductions, retained a uniform character throughout and showed no further loss of delicacy of demarcation and color than could be re-

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* We desisted from further reduction of diameter because of the invasion of bubbles.

ferred to diminution of thickness. Unfortunately it is not easily possible to discriminate between the effect of diameter and the possibly concomitant effect of lessened birefractive power. Hence these experiments fail to indicate whether the removal of consecutive shells by solution is accompanied by changes of strain (shrinkage). If the fragments of a shattered P. R. drop submerged in glycerin be examined under the microscope between crossed nicols, the presence of strain in many of the individual splinters is clearly apparent. It is well to note that marked polariscopic evidence of strain remains long after the explosive properties of the drop have disappeared. We infer that the electrical behavior (resistance) of the successive cores of a hard steel cylinder is not unexemplified by the optical behavior of successive cores of a P. R. drop; though it is difficult to say whether the behavior of the partial bodies in either case (partial strains) is at all comparable with the behavior of the bodies as a whole (temper strain).

In this place it is well to advert to certain important data of Table VI. Having removed two shells (total thickness $\vartheta_1+\vartheta_2=0{\cdot}04$) from each of the P. R. drops, Nos. 10 and 11, the density of the cores were found to be 2·4166 and 2·4147, respectively. We now annealed them in sulphur (450°) and found for the densities of the annealed cores 2·4263 and 2·4261, respectively. This increment of density is quite as large as is observed when the drops are annealed as a whole.* Hence we fail to appreciate any diminution of strain due to solution. Moreover we prove below that the increment of density observed on annealing at the said temperature 450° is a true increment of the density of the *substance* of the drop; that it is not due to a partial collapse of the bubbled P. R. drop in virtue of atmospheric pressure. The observed "*after-action*," in other words is inherent in the glass itself, as we pointed out elsewhere.†

Distribution of density in P. R. drops.

Results.—Availing ourselves of the property of the P. R. drop to dissolve quietly in hydrofluoric acid, we obtained the following results (Tables III and IV) for the variation of density along transverse radii of the drops. In these tables "Diameter" denotes the mean transverse thickness of the successive cores; M, Δ_0, their mass and density (0° C), respectively. Furthermore μ, ϑ, δ, R denote the mass, thickness, density and mean radius, respectively, of the consecutive shells. If the nth core be left after the removal of n shells, then the suffixes to the number of the P. R. drop in column first give the his-

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* L. c., p. 446.

† This Journal, III, xxxi, p. 452.

tory of the drops succinctly. Nearly all the measurements were made in duplicate. Δ_0 may be relied upon to within two units of the third place, δ to one unit of the second place. In no case was solution carried so far as to invade the main bubbles of the drops; they were chosen as nearly as possible free from small bubbles. The fusions were made in platinum baskets, suspended in thick clay crucibles.

TABLE III.—*Structure of P. R. Drops. Quenched.*

No.	Diameter.	M	Δ_0	μ	ϑ	δ	R
	cm	g		g	cm		
3_0	0·795	1·2576	2·4355	----	----	----	----
3_1	0·755	1·0375	2·4266	0·2202	0·020	2·478	0·387
3_2	0·725	0·8893	2·4210	0·1481	0·015	2·461	0·370
3_3	0·688	0·7650	2·4120	0·1243	0·019	2·479	0·353
5_0	0·825	1·3001	2·4400	----	----	----	----
5_1	0·786	1·0923	2·4347	0·2077	0·020	2·469	0·402
5_2	0·752	0·9317	2·4282	0·1606	0·017	2·473	0·384
5_3	0·720	0·8090	2·4181	0·1227	0·016	2·496	0·368

TABLE IV.—*Structure of P. R. Drops.*

No.	Diam.	M	Δ_0	μ	ϑ	δ	R	Remarks.
	cm	g		g	cm		cm	
7_0	0·763	1·0897	2·4386	----	----	----	----	Quenched.
7_1	0·746	1·0036	2 4346	0·0861	0·008	2·485	0·377	"
7_2	0·729	0·9254	2·4322	0·0781	0·008	2·462	0·368	"
7_3	0·712	0·8499	2·4288	0·0754	0·008	2·470	0·360	"
7_4	0·678	0·7363	2·4209	0·1136	0·017	2·482	0·347	"
7_5	0·641	0·6148	2·4098	0·1215	0·018	2·478	0·329	"
7_6	0·604	0·5136	2·3950	0·1012	0·019	2·489	0·311	"
7_7	0·539	0·3672	2·3640	0·1464	0·032	2·476	0·285	"
7_7	----	0·3102	2·495	----	----	----	----	Fused and cooled slowly.
8_0	0·790	1·1422	2·4396	----	----	----	----	Quenched.
8_1	0·775	1·0567	2·4372	0·0855	0·007	2·469	0·391	"
8_2	0·755	0·9739	2·4344	0·0828	0·010	2·471	0·382	"
8_3	0·738	0·9024	2·4317	0·0715	0·008	2·469	0·373	"
8_4	0·705	0·7741	2·4225	0·1283	0·016	2·489	0·361	"
8_5	0·667	0·6567	2·4129	0·1174	0·019	2·478	0·343	"
8_6	0·630	0·5460	2·4042	0·1107	0·018	2·457	0·324	"
8_7	0·558	0·3901	2·3743	0·1558	0·036	2·483	0·297	"
8_7	----	0·3424	2·498	----	----	----	----	Fused and cooled slowly.
9_0	0·758	1·0517	2·4390	----	----	----	----	Quenched.
9_1	0·744	0·9638	2·4370	0·0880	0·007	2·460	0·375	"
9_2	0·723	0·8689	2·4338	0·0949	0·010	2·467	0·366	"
9_3	0·707	0·7981	2·4302	0·0708	0·008	2·475	0·357	"
9_4	0·675	0·6931	2·4238	0·1049	0·016	2·474	0·345	"
9_5	0·636	0·5845	2·4161	0·1086	0·019	2·466	0·327	"
9_6	0·599	0·4866	2·4064	0·0979	0·018	2·465	0·308	"
9_7	0·536	0 3471	2·3765	0·1395	0·031	2·484	0·283	"
9_7	----	0·2779	2·501	----	----	----	----	Fused and cooled slowly.

Table V, constructed on the plan described for Tables III and IV, contains results for the variation of density along the transverse axis of drops annealed in boiling sulphur, 450°. Polariscopic examination showed these drops to be free from strain.

Table V.—*Structure of P. R. Drops annealed at 450°.*

No.	Diameter.	M	Δ_0	μ	ϑ	δ	R
	cm	g		g	cm		cm
1_0	0·767	1·1662	2·4398	----	----	----	----
1_1	0·710	0·8897	2·4242	0·2765	0·028	2·491	0·369
1_2	0·688	0·7859	2·4147	0·1038	0·011	2·503	0·350
2_0	0·932	1·8913	2·4420	----	----	----	----
2_1	0·874	1·4790	4·4303	0·4123	0·029	2·484	0·451
2_4	0·832	1·3118	2·4231	0·1673	0·021	2·484	0·426
6_0	0·795	1·2048	2·4468	----	----	----	----
6_1	0·740	0·9329	2·4350	0·2719	0·027	2·488	0·384
6_2	0·710	0·8436	2·4284	0·0893	0·015	2·504	0·362

In Table VI, finally, we give the results for the P. R. drops, Nos. 10 and 11. The first two shells were removed from the drops while in the original (quenched) state. Both were then annealed for two hours at 450° and a further removal of shells effected. The numbers referring to the annealed state are primed. In other respects the notation is that of the preceding tables.

Table VI.—*Structure of P. R. Drops.*

No.	Diam.	M	Δ_0	μ	ϑ	δ	R	Remarks.
	cm	g		g	cm		cm	
10_0	----	1·2984	2·4346	----	----	----	----	Quenched.
10_1	0·761	1·0766	2·4269	0·2218	(0·02)	2·473	(0·39)	
10_2	0·717	0·9014	2·4166	0·1732	0·022	2·481	0·370	
$10'_2$	0·716	0·9014	2·4263	----	----	----	----	Annealed, 450°, 2h.
$10'_3$	0·676	0·7425	2·4136	0·1589	0·020	2·488	0·348	
$10'_4$	0·637	0·6132	2·3982	0·1292	0·020	2·490	0·328	
11_0	----	1·0463	2·4357	----	----	----	----	Quenched.
11_1	0·719	0·8555	2·4281	0·1909	(0·02)	2·471	(0·37)	
11_2	0·680	0·7173	2·4148	0·1382	0·020	2·500	0·350	
$11'_2$	0·680	0·7173	2·4261	----	----	----	----	Annealed, 450°, 2h.
$11'_3$	0·635	0·5823	2·4086	0·1348	0·023	2·505	0·329	
$11'_4$	0·590	0·4678	2·3919	0·1148	0·023	2·479	0·306	

Discussion.—An inspection of Tables III and IV shows at once that Δ_0, the density of consecutive cores continually decreases. This is easily accounted for since the bubble error becomes relatively large as the mass, M, of the P. R. drop, decreases.

If we construct the density of consecutive shells, δ, as a function of their mean radius, R, and then compare the diagrams which obtain for the five P. R. drops (Nos. 3, 5, 7, 8, 9) we find that the loci have no salient feature in common. Hence the true variation of δ from surface to axis of a P. R. drop is here unrecognizably obscured by errors of observation. Indeed we shall find below that the probable total variation of δ attributable to strain will not far exceed 0·5 per cent. The mean accuracy of δ is certainly not much within this figure. Again if we compare the contours of corresponding curves, $\delta=f(R)$, in Table V for drops free from strain, with each other and with the contours belonging to Tables III and IV, we encounter fluctuations of the same kind in both cases. These errors include the inaccuracies of mere measurement (the mass of the drops is unfortunately small) as well as such discrepancies as result from the unavoidable invasion of small bubbles during solution.

If, however, we compare the *mean* values of δ for strained shells (Tables III, IV and VI) with the mean values of δ for shells free from strain (Tables V, VI), we find the latter values (unstrained glass) always in excess of the former. In other words, although our results are insufficiently sharp to enable us to describe the exact nature of the temper-strain in glass, they do permit us to classify it as a *strain of dilatation*, so far as we have observed, *throughout the substance of the drop.*. This is an inference of importance and we have therefore drawn up the following general tabular comparison, to supplement the special and direct comparison given in Table VI.

In Table VII, Δ_s is the density of the glass itself after thorough annealing at red heat, as found in our earlier paper,*—the datum being the mean value for six drops. Δ_s' is the density of the glass after *fusion* in a platinum basket and very slow cooling. The additional increment of the density of the glass thus produced is to be noted. δ_h and δ' denote the densities of shells, strained (quenched) and unstrained (annealed at 450°), respectively. The sixth column contains the relative value of decrement of density for each drop; the second column the number of shells whose average δ is the datum given.

To facilitate further comparison we insert also the corresponding table for steel.† Here 2ρ are the diameters of the steel rods, Δ_h, Δ_s, Δ_c, their densities in the hard, the soft and the commercial (soft) states, respectively. Δ', finally, denote the densities of steel at the end of the first phase of annealing (Ca 350°) and therefore apply for rods free from strain. The table gives us the following relative decrements of density: column first, the total decrement; columns second and third

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* L. c., p. 449.

† Bull. U. S. G. S., No. 27.

the decrements corresponding to the first and the second phases of annealing, respectively.

Tables VII and VIII show that both in the case of glass and of steel the mean strain effect of sudden cooling is *dilatation* throughout the substance of the quenched material;* that the amounts of mean dilatation for glass and for steel are of like order; that the strain in glass exceeds that of steel. We find, in general, that the practically measurable value of density is not a satisfactorily sharp datum for discerning the primary causes of the electrical, the optic and the magnetic variations

TABLE VII.—*Density relations of tempered glass relative to soft glass (mean results for shells).*

$$\Delta_s = 2{\cdot}491\,; \quad -\frac{\delta' - \Delta_s}{\Delta_s} = 0$$

P. R. Drop No.	No. of shells dissolved	δ_h	δ'	Δ'_s	$-\frac{\delta_h - \delta'}{\Delta_s}$
3	3	$2{\cdot}473 \pm 0{\cdot}006$	----	----	0·0076
5	3	$2{\cdot}479 \pm 0{\cdot}008$	----	----	0·0052
7	7	$2{\cdot}477 \pm 0{\cdot}003$	----	2·495	0·0060
8	7	$2{\cdot}474 \pm 0{\cdot}004$	----	2·498	0·0072
9	7	$2{\cdot}470 \pm 0{\cdot}003$	----	2·501	0·0088
10	2+2	$2{\cdot}477 \pm 0{\cdot}008$	$2{\cdot}489 \pm 0{\cdot}002$	----	0·0064
11†	2+2	$2{\cdot}485 \pm 0{\cdot}029$	$2{\cdot}492 \pm 0{\cdot}026$	----	0·0028
1	2	----	$2{\cdot}497 \pm 0{\cdot}006$	----	----
2	2	----	$2{\cdot}484 \pm 0{\cdot}000$	----	----
6	2	----	$2{\cdot}496 \pm 0{\cdot}008$	----	----
Mean	$(\frac{41}{10})$	2·476	2·492	2·498	0·0063

TABLE VIII.—*Density variations of tempered steel relative to soft steel.*

No.	2ρ	$-\frac{\Delta_h - \Delta_s}{\Delta_c}$	$-\frac{\Delta_h - \Delta'}{\Delta_c}$	$-\frac{\Delta' - \Delta_s}{\Delta_c}$
I	1·90	0·0048	0·0018	0·0029
II	0·58	0·0155	0·0060	0·0095
61 to 63	0·13	0·0171	0·0068	0·0103
0	0·23	0·0133	0·0080	0·0053
21 to 29	0·08	0·0150	0·0033	0·0116
Mean	----	0·0131	0·0052	0·0079

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* If "quenching" means sudden cooling, then if the solid quenched be massive and thick, the inner layers cannot be quenched in virtue of their position. In the above Tables a general increase of the shell density from the surface inward is indistinctly apparent. But the evidence is not sufficient.

† In view of the large value of probable mean error of this measurement we thought seriously of rejecting it. But we were unable to find any error in the work and hence the datum has been retained. Its effect is principally apparent in the ratio, depressing it in a way adverse to our inferences.

of the substance quenched. These therefore are alone available for the nice descriptions of strain and for the interpretation of what we called elsewhere the individuality of magnets.

With the above pages we have pursued the analogy between the optical behavior of tempered glass and the electrical behavior of tempered steel into every detail of consideration which urged itself. We availed ourselves moreover of additional criteria given by the density relations of the whole or of similar parts of the bodies quenched. At every stage of our work we reached data alike in character both for steel and for glass. With these results we are justified in maintaining that sudden cooling of steel is accompanied by a strain-effect of a distinct and individual kind and of an intensity sufficient to account for the electrical properties of steel (thermo-electric and resistance constants) such as we have found them.

In one of the earlier paragraphs of the present paper we pointed out that in its divers relations to hardness steel is distinguished from glass. To further our investigation it will therefore next be necessary to inquire more specifically into the causes of hardness itself, and therewithal to endeavor to throw light on the mysterious transformations of carbon.

Washington—Prague, June, 1886.

ART. XX.—*Devonian Lamellibranchiata and Species-making;* by HENRY S. WILLIAMS.

THE second portion of Professor James Hall's monograph* on Devonian Lamellibranchs has been recently published, thus completing volume v, Part I, of the Palæontology of New York. The first portion was devoted to the Monomyaria. This second volume is devoted to the Dimyaria, is dated 1885, contains pages i to lxii, and 269 to 562, and plates xxxiv to xcvi with interleaved explanation of plates. The number of species described is 284, which are referred to 47 genera. Nine new genera are described; *Euthydesma* (type, *Astarte subtextile* Hall), *Sphenotus* (typical species, *Sanguinolites arcæformis* Hall, and *Cypricardia contracta* Hall), *Spathella* (type, *Spathella typica* Hall), *Glyptocardia* (type, *Venericardium retrostriatum* von Buch, *Cardium palmatum* Goldfuss, *Avicula speciosa* Hall), *Pararca*, (types, *Pararca venusta* Hall, and *Pararca erecta* Hall), *Prorhynchus* (type, *Palæanatina quadrata* Hall),

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* Palæontology, vol. v, Part I, Lamellibranchiata II, text and plates. Containing descriptions and figures of the Dimyaria of the Upper Helderberg, Hamilton, Portage and Chemung groups; by James Hall, State Geologist. Albany, 1885.

Glossites (type, *Glossites lingualis* Hall), *Elymella* (type, *Elymella nuculoides* Hall), *Protomya* (type, *Protomya oblonga* Hall), one subgenus, *Palæosolen* (type, *Orthonota siliquoidea* Hall), and 79 new species. The drawing and engraving are excellent; and, next to having the type specimens, these illustrations are of great value to paleontologists, who owe thanks to the Board of Regents, who have gotten this volume finally published.

The first part of the volume, published in 1883, contains pages i to xviii, 1 to 268, and Plates I to XLVI. The complete work contains 642 pages and 96 plates, and it figures and describes 520 species and 65 genera. It is a magnificent work, placing before the student figures and descriptions of all the known species and varieties of the Devonian Lamellibranchiata of Eastern United States; it will take its place among the indispensable monographs on the table of the working paleontologist.

The illustration of these Lamellibranchs, as a whole group, was begun in 1869–70, in the issue of a pamphlet, called Preliminary Notice of the fossil Lamellibranchiata, etc., No. 2, 80 pages of which appeared, and a few copies of which were distributed in 1869. The title page of this pamphlet contained no author's name, it was accompanied by no plates. In 1884, Preliminary Notice No. 1 appeared in the 35th Report of the Regents on the State Museum.

The final text and plates of the part on Monomyaria appeared in 1883; and, finally, the part on the Dimyaria was published in 1885. In the mean time the Report of the State Geologist to the Legislature for 1882 (published in 1884, Assembly Documents 1882, vol. vii, No. 32), announced and published the diagnoses of 20 genera, all of which were new or restrictions of old genera, and, with the text were issued eleven plates of generic illustrations, in the explanation of which 54 genera and 134 species are named. Most of the plates of this double volume were completed several years before their publication, or before the text was finished. As early as 1874 sets containing a considerable number of the plates, with manuscript names, were sent out to Messrs. S. A. Miller, Dr. J. J. Bigsby, J. Barrande and Henry Nettleroth. (See plates and explanations, 1883, Preface, pp. 1 and 2.)

Mr. Miller published in his American Paleozoic Fossils, 1879, the names of these new species with reference to the forthcoming work, apparently under the advice and supervision of the author. Dr. Bigsby also published in 1878 the names attached to these plates in his Thesaurus Devonico-Carboniferus. Thus a large number of new names became quoted with references to author and plate and figure and locality, before the text was even in the hands of the printers, reference being made to plates, but no mention of the fact that they were manuscript names.

This action aroused serious criticism, although little was made public. And, although the author doubtless expected to get the volume out very soon, it was not till 1883 that paleontologists received the plates. So much impatience was evident that the author, being unable to persuade the Legislature to publish the volume, bought a hundred sets of the plates and distributed them in 1883 to the chief institutions and workers interested in the subject in this country. With the plates were given printed explanations of plates, and the announcement was made that the text was ready and in the hands of the printer.

Much confusion and annoyance has arisen from this preliminary distribution of plates, and *publication* of names so long (at least seven years) before the regular publication of the text and plates. But, aside from this, impatience naturally becomes extreme when we look at the prodigious amount of alteration which has been made in the identification, both specific and generic, in the plates illustrating the fossils supposed to be representative types. Comparison of the plates and explanations issued in 1883 with the text and plates issued in 1885,—the plates being the same with a few additions in the latter,—reveals the following facts.

In the first set of statistics, I have compared only those species and genera both of which, in both works, were already fully described when the first work was issued in 1883. The changes made in identification of the figures, representing 284 species and 47 genera (the plates being identically the same) were 81 in number as regards the genera, and 128 as regards the species.

If now we consider the figures which were referred in 1883 to old species, and in 1885 to new species, we find 96 cases, and of figures placed in old genera in the first case and changed to new genera in 1885, we find 117 cases.

Looked at from another point of view, and eliminating from the problem all matter added in 1885 and all specific and generic names not fully described and used *before* the first publication, 1883, there were made 209 changes of identification for 205 species under consideration.

If we take the plates published in the Report of the State Geologist to the Legislature for 1882, printed in 1884, and compare the identification of the figures, which are there reproductions of those in the text and plates of 1885, a similar set of discrepancies appears.

This Report was issued, professedly, as an official illustration of generic types or representative species of those genera, and 34 genera were illustrated; when we compare it with the final report, published only one year later, we find 19 cases of changed generic identifications, or, proportionate to the number of genera 50%, and 24 specific changes or nearly 35%.

Both these works, the plates and explanations, 1883, and the generic illustrations, 1884, were issued by the State Geologist as authoritative works illustrating the typical specimens, described mostly by him, in the State collections; specimens which had been picked out as typical for the draughtsman, and not only had they been identified by him, but they had been used in the very descriptions of genera and species for the illustration of which they were published.

In the final work, 1885, their generic and specific names are changed, in most cases with no reason given, occasionally with the note "by error" inserted in the list of synonyms. These alterations are not a simple few, but for the plates and explanations, there is an average of one alteration of identification for every species in the book. There is no disputing the facts; anyone can find them by mere comparison of the two volumes.

It seems impossible to suppose that such errors could be due to carelessness of observation; the life-time experience of the author, and his acknowledged first rank among paleontologists forbid such an explanation, and we have no reason to suppose that the identifications are not in all cases his own.

The only explanation we can conceive of is found in the system itself upon which the species are conceived and defined. Species-making and illustrating fossil forms are not the same thing. To have good figures of the most perfect typical fossil forms is of the greatest value to the student of paleontology but, if they are classified into species and genera it is all important that the differentiating characters should be discernible, at least on the typical specimens, and that too, not by experts only, but by any ordinary intelligent observer.

When we see 57 species made of a group of fossils, in which the surface is practically without differentiating characters, all the elements of form the same, showing only differences in contour, with a slight range of difference in convexity and in the angle made by the umbonal ridge with the cardinal margin, and in the points used for specific distinction with scarcely two specimens alike, we think it is asking too much of students to accept the species as of value, or to expect him to recognize them. Our hesitation is confirmed when, as in the case of the genus "*Leptodesma*," we read, as the most important distinctive character of the genus, that "the anterior end is always nasute and acute instead of auricular and rounded" (as in

"*Leiopteria*"), while in the figures we find specimens fully as "auriculate" as in several representatives of the other genus, and in the description of half a dozen species of Leptodesma we find the distinct statement that the anterior end is "round."

In another new genus, for which about a score of species are defined, the writer has seen a series of specimens, picked out of a single block of stone, expressing, by almost imperceptible gradation, almost every character exhibited by the whole range of species figured except difference of size.

The evil of this species-making habit is only aggravated by the minuteness and carefulness of the observer, and in the study of fossils it is particularly aggravated by the rarity of good specimens and the imperfection of the characters expressed. In its extreme it has ceased to be a classifying of organisms, or even fossils, and has become merely a narration of the differences exhibited by specimens.

And when a student seeks to identify new material, the more careful his scrutiny, the more surely is he driven to the idea that specimens which do not fit any of the given descriptions must be new species. So long as the Cuvierian school prevailed, there was some excuse for the practice, but in this age when the belief in the fixity of specific characters and limits is shown by theory and observation to be erroneous, there is no reason for neglecting the element of variability as a factor in the classification and definition of organisms, whether living or fossil.

The practice of differentiating species (and genera) by characters which are not clearly discernible on every fair set of the representatives of the species, or by characters which in point of variability among individuals from the same locality exceed the extent of modification separating two species of the same genus, is scarcely defensible, and leads to more confusion and uncertainty than if merely numbered photographs were distributed as illustrative of the fossils of each period and locality. If such rules were thoroughly heeded by working paleontologists the crop of new species would dwindle, but the species which were entitled to live would be capable of distinct definition and recognition.

Species and genera can scarcely be called good, so long as the author himself is unable to distribute the typical specimens, twice alike, without reference to the original labels.

In regard to the genera a word may be said: the author has retained the genus *Microdon* Conrad, although it is pre-occupied by Agassiz for a genus of fishes, and the genus *Cypricardella* Hall is acknowledged to be identical, as was shown by Mr. Whitfield (Bull. Am. Mus. Nat. Hist., vol. i, No. 3, p. 63). The first name is used with the second placed parenthetically after it. This only complicates the matter, and the 10th of the British Association rules forbids the retention of *Microdon.*

The genus *Cytherodon* Hall, was first figured in 1872 (23d Reg. Rept., Pl. 14, figs 19, 20 and 21), with the name but with no description. The figures, 19 and 20, were *Cytherodon tumidus* Hall and *Nuculites appressus* Conrad, and 21 was specifically unnamed. In Plate VIII of generic illustrations, 1882 (publ. 1884), figs. 19 and 21 are reproduced, and both are given as illustration of the genus *Schizodus*, and the specific name *nasutus* is given to the original specimen, figured from a cast in fig. 21. In the final volume the specimens, figured as 19 and 20, are referred to *Schizodus*, and only the single specimen, represented by fig. 21, is left to represent the genus *Cytherodon.* Thus it appears that the specimen which ultimately becomes the type and sole representative of the genus *Cytherodon* Hall, was named and described and referred to the genus *Schizodus*, after *Cytherodon* was proposed as a genus distinct from *Schizodus.*

Conocardium Bronn, has no relation to the Cardiadiæ, a fact heretofore unknown and brought to light by Dr. Lindström and communicated by letter to Prof. Hall. (See note, p. xxxiv). The forms hitherto generally referred to *Cardiola* are identified with Barrande's genus *Panenka.*

The genus *Glyptocardia* is proposed for the forms called *Venericardium retrostriatum* von Buch, *Cardium palmatum* Goldfuss, *Avicula speciosa* and *Cardiola speciosa* Hall.

Modiella is said to be "in all respects very similar to some recent forms of *Modiola.*" Why then propose a new genus?

The genus *Sanguinolites* M'Coy, is discarded for all the species formerly referred to that genus, and only used for two species which formerly were called *Edmondia.* The species originally called *Sanguinolites* are distributed among two new genera, *Sphenotus* and *Spathella*, and the old genus *Orthonota* Conrad.

A glance at the distribution of the *Lamellibranchs* and their range geologically, discovers the following facts. The species of the Marcellus, Genesee and Portage groups are mainly found to belong to the same genera, and these genera are rarely found in the Upper Helderberg, Hamilton or Chemung; and *vice versa*, the prevailing genera of the Hamilton and Chemung faunas are rarely found in the Marcellus, Genesee or Portage. A study of the Chemung species shows that the species common in the more western exposures are rare in eastern New York. Of the Dimyaria, the genera beginning in the Hamilton reappear more frequently and abundantly in the Ithaca group and among eastern representatives of Upper Devonian, and in the western sections they do not appear till near the close of the Chemung, or till the Waverly. The characteristic forms associated with the general Chemung fauna in western New York are the Monomyaria, which are less abundant in the eastern sections. The Ithaca group of Lamellibranchs are more closely allied with the Hamilton than with the Chemung forms.

The species and even the genera of Lamellibranchs, as here represented, appear to be much more sensitive to conditions of environment than are the Brachiopods, as shown by the association of certain species and genera with particular kinds of deposit. The fauna of the coarser sands toward the termination of the Chemung period presents a clearly defined set of Lamellibranchs,—as the *Palæanatinas*, the "*Ptychopterias*," certain of the *Grammysias* and *Sanguinolites*="*Sphenotus*."

In his remarks upon the classification of the rocks of the Devonian, Professor Hall appears rather to add to the confusion than alleviate it. The Oneonta reds and grays, although lithologically indistinguishable from genuine Catskill rocks, and containing unmistakable *Bothriolepis* scales (a genus hitherto regarded as characteristic of the Catskill deposits), is distinguished from it, "and forms no part of the Catskill group" (p. 518).

It is stated (p. xix) that "it has not been shown that" [the Ithaca] "formation is distinctly separated from the typical Chemung lying above," and, I suppose, it is for this reason that on page 538 we find the note that "The Chemung group is here intended to include all the strata between the Catskill and Portage groups. In this volume the strata at Ithaca have been referred to the lower portion of the Chemung group." The facts are that the fossiliferous zone at Ithaca is separated from the lowest beds containing characteristic Chemung fossils by about six hundred feet of nearly barren, flaggy and shaly deposits, but with a few fossils which belong to the characteristic Portage fauna. Also the Oneonta rocks, going westward, gradually merge into the rocks which at Ithaca contain the fossiliferous beds, but on page 517 it is said "this portion of the series apparently merges into succeeding Portage groups of which further west it forms a part."

There is here some confusion. Although it would be difficult to distribute in a continuous column the several distinct local representatives of the upper Devonian for New York and Pennsylvania, it is unfortunate to throw together species of two zones so distinct as those at Ithaca and the typical Chemung zones higher up. The Ithaca fauna and its equivalents are wanting in the more characteristic of the Chemung species, and its whole facies links it as intimately with the Hamilton as with the typical Chemung fauna.

Ithaca, N. Y., April 27, 1886.

ART. XXI.—*Notes on the Composition of Certain "Pliocene Sandstones" from Montana and Idaho*; by GEORGE P. MERRILL.

A YEAR or more ago, while attempting to classify and arrange the rocks of the collections made in Montana and Idaho in 1871 by Dr. A. C. Peale of the Hayden Survey, my attention was called to a series of fragmental rocks from Little Sage Creek, Beaver Head Cañon, Devil's Pathway, Marsh Creek Valley and Port Neuf Cañon, which were labeled as "Pliocene" sandstones. A single glance showed me that these could not be ordinary sandstones, but that they bore a striking resemblance to compacted volcanic dust and sand. A glance at a portion of the dust rubbed from the specimen with the thumb and finger and placed under the microscope was sufficient to confirm my first conclusions, and to show that the stones consisted very largely of minute flakes of pumiceous glass sufficiently compacted to be readily broken out into hand specimens, but yet so friable that in most cases they could be easily disintegrated by the thumb and fingers. On mentioning the fact to Dr. Peale, this gentleman expressed great interest in the matter, and requested that I make a further examination and put my results upon record for purpose of future reference. This I have accordingly done below.

Little Sage Creek, Montana.—Three varieties of the sandstone were found from this locality, one (35890*a*)* a fine-grained, light gray and rather friable rock, quite homogeneous, and with a sharp gritty feel, agreeing closely in appearance with a pumiceous clastic rock from Citadel Cliff, East Fork of Holmes Creek, collected by the 40th parallel survey. Portions of the dust rubbed off and placed under the microscope showed it to consist wholly of a very light smoky brown, completely amorphous, glass, with the sharp angles and peculiar curved sides so characteristic of pumiceous glasses when in a finely divided state (fig. 1).† Between crossed nicols there is seen rarely a polariz-

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* The numbers given refer to the catalogue number of the specimen in the Museum collection.

† Other figures showing the appearance of volcanic dust as seen under the microscope are given in the following papers: On Volcanic Ashes and Cosmic Dust, Nature, April 17th, 1884; Volcanic Sand which fell at Unalashka, October 20th, 1883, Science, May 30th, 1884; and on Volcanic Dust from Southeastern Nebraska, Proc. Nat. Mus., vol. viii, 1885, p. 99.

ing fragment, and there are also present a few particles of earthy matter.

A second variety (35890*b*) is coarser, has a marly appearance, and effervesces slightly under dilute acid, showing the presence of calcite. The microscope shows but few particles of pure glass, but very many that resemble the pulverized amorphous groundmass of modern lavas. There are also a few crystalline particles too small for accurate determination, but which are probably feldspar, and other greenish dichroic ones apparently hornblendic.

A third variety (35890*c*) from this same locality is of slightly coarser texture than either of the last, of a light gray color and distinctly laminated. It contains a very considerable proportion of crystalline calcite which evidently serves as a cement. Fragments of the stone after treatment with dilute hydrochloric acid to remove the calcite are found to consist largely of colorless pumice dust, a few cleavage fragments of feldspar, folia of deep greenish brown mica, and a few earthy and ferruginous particles.

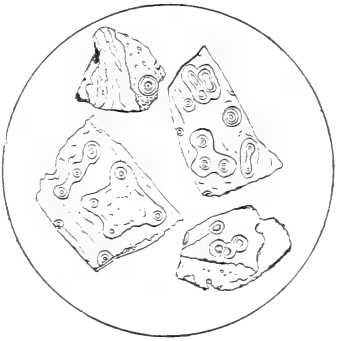
Still a fourth variety (35890*d*) is yet coarser and much firmer in texture, of a light buff color, and appears much like an ordinary fine-grained siliceous sandstone. Under the microscope the individual particles are found to be both quartzose and feldspathic (judging only from appearances, no measurements being possible), with comparatively few flakes of pumice dust. All are much eroded, and have evidently been subjected to attrition by moving waters more than any of the others from this locality.

Beaver Head Cañon.—We have but a single specimen from this locality and this (35891) like the last mentioned, except slightly coarser and with minute flakes of black mica. Under the microscope a few polarizing particles are seen but they are too small for accurate determination. The glass particles are small but stout, and lack the sharp angles noted in the other varieties. They are considerably water-worn.

Devil's Pathway.—But two samples were received from this locality. The first of these (35893*a*) is fine-grained, and light ash color like the finer varieties from Little Sage Creek and Marsh Creek Valley. Like them too it is composed entirely of pumice glass, but of a peculiar appearance such as I have never before seen, nor do I remember to have seen it described. Each fragment, however small, appears, under a power of 105 diameters, to bear upon its surface several or many minute disc-like bodies, colorless and nearly circular in outline. Under a power of 420 diameters these are seen not to be in all cases perfectly circular in outline, but several often coalesce forming continuous chains of irregular form, such as are nicely shown in the accompanying figures (fig. 2) from Mr. Ridgeway's drawing. I can think of nothing with which they compare in appearance more nearly than that of lunar landscapes, as illustrated in works on popular astronomy.

The second variety from this locality (35893*b*) is a fine-grained, compact, dark brownish gray rock, bearing little resemblance to the others described. It is not at all friable but effervesces readily with acid. Fragments after treatment with acid till they no longer give off bubbles fall readily to a powder, which the microscope shows to consist almost wholly of quite large pumice fragments, sometimes colorless but often stained a bright yellow by ferruginous matter. A few crystalline particles are present but so stained as to be unrecognizable. The glass in this sample shows no trace of the peculiar disc-like bodies noted on the last.

2.



Marsh Creek Valley, Idaho.—Of the four samples from this locality the first two (35889*a*) like 35890*a* from Little Sage Creek, are nearly pure pumice dust, but the particles have suffered more from attrition, and are so filled with minute cavities as to have a dirty appearance under the microscope. The rock is ash-gray and has a sharp gritty feel.

The second (35889*b*) is much firmer in texture, laminated, slightly coarser and contains black particles. Its composition is, however, practically the same with the addition of a little calcite which serves as a cement. The rock effervesces readily under dilute acid, and the residue is all glass with no crystalline particles whatever.

The fourth specimen (35889*c*), although coarser and of a brownish color, is also largely pumice dust, but the particles are quite dirty-appearing under a low power, an appearance which a power of 420 diameters shows to be due to their rough, almost granular surfaces. There is but little calcite present.

Port Neuf Cañon.—The two specimens (35892) from this locality compare closely macroscopically with the finer varieties from Little Sage Creek and Marsh Creek Valley. Like them too they are composed wholly of minute fragments of pumice (fig. 3).

These last, like some of the others mentioned, contain evidently two kinds of pumice dust. The one occurs in colorless shreds with curved outlines, which rarely contain tubes or steam cavities even in the larger forms. The other, however small the fragments may be, is always pumiceous through the presence of innumerable bubbles and tube-like cavities; a slight difference in viscosity of the original magmas having evidently caused one to become coarsely vesicular, which on breaking up through the sudden explosion of the included steam gives rise to fragments each one of which represents a portion of the partition between the cavities or vesicles, while the other, through being more finely pumiceous, gives fragments each one of which, however small, still shows its true pumiceous character. These facts are not indicative of any difference in chemical composition, but as one or the other of the forms is usually found to prevail in samples from various localities the matter seems worthy of note.

All of the above mentioned dusts yielded water when heated in a closed tube, and fused readily, with swelling, before the blowpipe. Samples submitted to Mr. J. E. Whitfield of the Geological Survey for analysis yielded results as follows:

	(35889*a*)	(35890*a*)	(35893*a*)
Ignition	6·00	6·50	5·60
Water*	1·60	1·12	3·46
$Fe_2O_3+Al_2O_3$	16·22	18·24†	17·18
SiO_2	68·92	65·56	65·76
CaO	1·62	2·58	2·30
MgO	trace.	0·72	trace.
Na_2O	1·56	2·08	2·22
K_2O	4·00	3·94	3·14
	99·92	100·74	99·66

Accepting the apparently well founded conclusions of others‡ to the effect that such dusts represent the extreme degrees of acidity of the lavas of which they formed a part, we are led to consider these as of andesitic or possibly trachytic derivation.

Samples, subsequently submitted by Dr. Peale from above Pass and Bridger Creeks near Bozeman, have also been examined.

The first of these (38448), marked as "Dry Creek Pliocene," is a fine-grained friable aggregate of a light yellowish gray color. Tested with acid it was found to contain a little lime, but consists chiefly of glass particles very pumiceous and stained by iron oxides.

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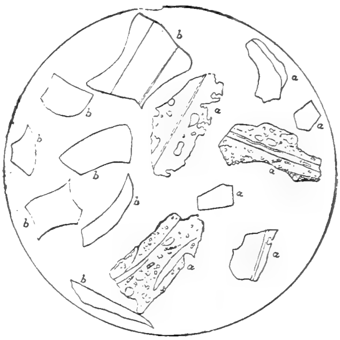
* Water given off at 105° C.

† Mostly FeO. Mr. Whitfield appends the following note: These analyses not checked by duplicates, there being but a small amount of material, therefore the iron is put down as *ferric* when most of it is *ferrous*. The ignition, therefore, is not as high as it should be by reason of the oxidation of the FeO to Fe_2O_3, but is partly balanced by entering the iron as Fe_2O_3.

‡ See Science, May 30, 1884.

A second variety (38447) from the south side of Bridger Creek, on summit of hill near Bozeman, is like the last but somewhat coarser, and contains also a few colorless polarizing fragments and particles of hornblende. A variety (38450) from the "upper beds," south side of the creek, is of a brown-gray color like that of Dry Creek. It is composed almost wholly of very pumiceous glass like fig. 3. Still a fourth sample (38449), from a bed just below the last is gray in color and much coarser, the fragments being in some cases $0{\cdot}74^{\mathrm{mm}}$ in greatest diameter. It contains also a few polarizing grains.

3.



Small particles of pumice glass were also found in connection with sundry fossil bones from the Niobrara, Loup Fork and Sweetwater regions. These bones had been quite thoroughly cleansed and handled over many times so that very little of the material in which they had originally been imbedded remained. Nevertheless by carefully picking between the teeth, in cavities and protected places, sufficient material was obtained for microscopic examination which resulted as noted.

While working upon the above, several other instances of the occurrence of this dust came to my notice which perhaps may be of sufficient interest to mention here. One of them sent by a friend in Phœnix, Arizona, is of a white and gray color sufficiently compacted to be cut in blocks of considerable size, and is stated to have been used to some extent for building purposes. It is stated to occur in "blankets" from three to fifteen feet thick, more or less tilted, and cropping out near the base of the Mazatzol Mountains at the edge of Verde River valley. The microscope shows this to be composed of pumice fragments of about $0{\cdot}25^{\mathrm{mm}}$ greatest diameter, and apparently identical with that described by myself from Southwestern Nebraska* (see fig. *3b*), and quite similar to that from east of the Black Hills, Dakota, described by Dr. Wadsworth in Science of July 24, 1885, a sample of which he has been kind enough to send me.

About this same time Mr. R. T. Hill, of the Geological Survey, brought me a sample of similar dust which he had collected from near Wray Station (B. & L. R. R.) in Eastern Colorado, on the south side of the Republican River (38430), and a few days later others were brought in by Dr. Peale

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* Proc. Nat. Mus., vol. viii, p. 99.

which had been received from Norton (38439) and Phillips (38446) Counties, Kansas. All were pure glass in particles never over 0·3^{mm} in greatest diameter and usually much smaller. They agree closely with those just mentioned, and also with that lately mentioned by Mr. Todd* as occurring in Eastern Nebraska.

In studying the probable origin or sources of these various beds, the distances which the dust can be carried by atmospheric currents is likely to prove of importance. It may therefore not be out of place to state here, that among a collection of pumices, ashes, etc., from the Krakatoa eruption in 1883, and which were donated to the Museum by T. H. Houghton, was a small sample of the dust (36974) that "showered on board ship Beaconsfield at the rate of one inch per hour for three days, in latitude 14° S., longitude 92° E., or at a distance of 855 miles from the scene" of volcanic activity. This dust is a very pure, nearly colorless, gray and highly pumiceous glass, the particles of which vary in size all the way up to 0·25^{mm}.

As a matter of economic interest I may say in conclusion that in Kansas and Nebraska these dusts are collected and sold in paper packages as "diamond polishing powder," or put into soap which is sold for general scouring as well as for dental use under the name of "Geyserite" soap.

National Museum, Washington, April 30th, 1886.

ART. XXII.—*Contributions to Mineralogy* by WM. EARL HIDDEN; *with Crystallographic Notes* by A. DES CLOIZEAUX.

1. *North Carolina Mineral Localities.*†

SPODUMENE.—Many transparent crystals of this species were discovered last summer on the land now known as the Morton tract. This new locality, for spodumene, is situated in Sharpe's Township, Alexander Co., and is distant one-third of a mile nearly west from the original discovery shaft of the Emerald and Hiddenite Mining Company. This locality has already furnished some very highly modified crystals of quartz, tourmaline and beryl,‡ and also some inferior crystals of spodumene. The writer was led to believe that the *gem variety* of the spodumene might be found there by the similarity of the quartz crystals found on the surface to those from the gem-bearing pockets on the neighboring land. These quartz crystals have the planes + and − 3R predominating, or they enclose silky fibers of a mineral related to amphibole. In the excava-

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* Science, April 23d, 1886.

† Continued from vol. xxiv, Nov., 1882.

‡ This Journal, Nov., 1882; Geol. N. C., 1881, p. 92.

tion last summer, in the search for spodumene gems, on this Morton tract, the quartz crystals above described frequently occured in the top soil; the miners here call them "hiddenite-quartz."

In a period of three months' work, nine well defined pockets of yellowish and emerald-green spodumene (hiddenite) were discovered, but the aggregate yield was comparatively small. Very few perfect crystals were found suitable for gems, but some were successfully cut. It is thought that the material may improve when the hard rock is reached; at a depth of 20 feet the loose sandy disintegrated rock remains unchanged. With the spodumene were found a few beryls of some merit as to transparency and color; great numbers of quartz crystals, some of remarkable form; a few brilliant and highly modified crystals of black tourmaline (see below); some monazite and many small crystals of ruby-red rutile mostly associated upon or within quartz crystals. Among the spodumene crystals were a few that were doubly-terminated and of a new type of form for the region, the prismatic planes being only slightly developed. These crystals were nearly colorless, quite large and semi-opaque.

The following communication from Professor Des Cloizeaux (dated Paris, Feb. 4, 1886) gives the values of the indices of refraction of this species, and shows that its refractive power is only slightly higher than that of tourmaline:

> "Physically the hiddenite is identical with the yellow triphane (spodumene) of Brazil. Thanks to the new refractometer just announced by Emile Bertrand, in the Bulletin de la Société Minéralogique, it is now possible to obtain the three indices of refraction from uncut or cut sections. A first approximation gave for hiddenite $\alpha = 1{\cdot}677$; $\beta = 1{\cdot}669$; $\gamma = 1{\cdot}651$ for yellow rays. I afterwards found $\beta j. = 1{\cdot}669$ for the triphane of Brazil, cut on the prism."

Black Tourmaline.—The tourmalines, incidentally alluded to in the preceding note on spodumene, occur implanted in cavities similar to the other crystals of this region. They are noteworthy from the brilliancy and number of the planes presented. With a hand goniometer I identified the following: O, I, i-2, R, 1, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{5}$, $\frac{5}{4}$, 2, 3 and $\frac{1}{2}^3$—twelve planes in all. Several others were noticed but their angles could not be determined with the means at hand. One crystal presented only the planes $\frac{3}{5}R$, $\frac{1}{2}R$ and O all equally developed, $\frac{3}{5}R$ being new. None of the crystals were over one inch in diameter and two inches long. On many of them, minute ruby-red quadratic crystals of rutile were implanted, having the basal plane. Through thin edges these tourmalines had a deep brown color, and the smaller crystals were translucent. $\frac{3}{5}R$ measured on O

gave 149° as the approximate angle. R on R adj.$=103°$. Occurring with them were some few quartz crystals of remarkable form. Three of the most perfect presented only an upper trapezohedron ($-\frac{15}{14}\text{-}\frac{15}{14}$?) in the termination, the unit rhombohedron not appearing even in traces. Others were hemimorphic, having several acute rhombohedrons (2, 3, 6 and $10R$?) at one extremity, and only R at the other.

XENOTIME.—Some few beautiful crystals of this rare species were discovered in the early part of last year at a locality situated about three miles east of the Emerald and Hiddenite Mine, in Alexander Co., N. C. These were found among quartz crystals, considerable rutile in the form of fine yellow needles matted together and some remarkable crystals of monazite (see p. 207). Only about one dozen crystals were found and these were discovered by washing carefully the whole of the pocket material. The color of the crystals is hair-brown, and some of them are perfectly transparent. Specific gravity $=4{\cdot}45-4{\cdot}52$. Cleavage prismatic, easy. Habit long prismatic, and in this particular differing from other American xenotimes.

My own measurements with a Fuess reflective goniometer gave as a mean of many determinations of the angle $1 \wedge I$ 131° 14′; the measurements varied from 131° 9′–131° 19′. Upon these crystals I identified with a hand goniometer the planes: I, 3, 1, 3-3 and O in traces. Of these the plane 3 is new to the species, while 3-3 has been observed by Brezina, and later by Hessenberg, Klein and Brögger. The habit of the North Carolina crystal is very closely similar to that of a Swiss crystal figured by Klein;* they are well represented by figs. 251, 252 of zircon in Dana's System of Mineralogy.

A few of the crystals were sent to Professor Des Cloizeaux, and of them he says:

> "Notwithstanding the beautiful appearance of these crystals of xenotime, they present no faces sharp enough to furnish precise measurement of angles; which is to be regretted, as all angles published until now are alike uncertain. They oscillate between those of Dana and those of Brögger taken on crystals from Norway (Geol. För. Förh., Stockholm, Dec., 1883). The following are my angles:
>
> $b^1\ b^{\frac{1}{3}}=(1 \wedge 3)=152°\ 25'-35'$; $b^1\ m=(1 \wedge I)=131°\ 15'-45'$; $b^{\frac{1}{3}}\ m=(3 \wedge I)=159°\ 10'-30'$; $b^{\frac{1}{3}}\ a_2=(3 \wedge 3\text{-}3)=155°$ approx.; $b^{\frac{1}{3}}\ b^{\frac{1}{3}}$ over $a_2=(3 \wedge 3$ over $3\text{-}3)=97°$ approx.; $b^1\ b^1=(1 \wedge 1$ adj.) 124° approx.
>
> Brögger gives $1 \wedge I=131°\ 31'$, $1 \wedge 1$ adj. 124° 6′. Dana's angles $O \wedge 1=138°\ 45'$, $1 \wedge I=131°\ 15'$."

The smallest crystal measures 3^{mm} square and 5^{mm} long, while the largest was nearly 20^{mm} long and 10^{mm} thick. One trans-

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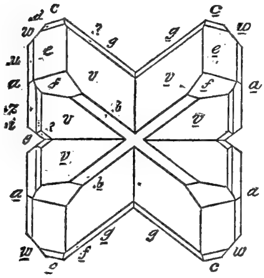
* Jahrb. Min., 1879, 536.

parent crystal having a prism of 4^{mm} square, was 17^{mm} long and had the zirconoid 3-3 and 3 largely developed. An analysis by Mr. J. B. Mackintosh showed the presence of 34·05 per cent of phosphoric acid combined with a base considered to be yttria but not tested.

In the auriferous gravels of middle western North Carolina, northwestern Georgia and eastern Alabama, the writer has frequently found xenotime along with monazite, etc. Some of the localities are in Hall Co., Ga., Burke, Polk and McDowell Counties, N. C. I have been most successful in the drift from the Pilot Mt. in the lower edge of Burke Co., N. C., where I found some of the xenotimes symmetrically compounded with zircon (vol. xxi, p. 244, 1881).

TWIN CRYSTALS OF MONAZITE.—In the preceding note on xenotime the occurrence of these beautiful monazite crystals is briefly mentioned. With the single exception of the crystals from this region which formed the basis of Dr. Edward S. Dana's paper,* probably no finer examples of this rare mineral have ever been found. For the most part the crystals are transparent, of a beautiful essonite-red color and are highly polished. They vary in size from four to twenty millimeters in length and thickness. They were prismatic from an unusual extension of $+1$ and $+1\cdot i$. The occurring planes, as shown in the figures, are:

1.



$a = i\text{-}i$ (100), $w = -1\text{-}i$ (101), $c = O$ (001), $g = +1\text{-}i$ ($\bar{1}01$), $d = \frac{1}{2}\text{-}\grave{i}$ (012), $e = 1\text{-}\grave{i}$ (011)
$f = 2\text{-}\grave{i}$ (021), $b = i\text{-}\grave{i}$ (010), $v = +1$ ($\bar{1}11$), $z = +3\text{-}3$ ($\bar{3}11$), $i = +2\text{-}2$ ($\bar{2}11$), $u = -1$ (111)

In addition there were i-2, $-2\cdot\grave{2}$, I and several other planes which were only slightly developed, and an undetermined orthodiagonal pyramid. Of the above, v, a, g, z and e were the most frequent and predominating planes, while the prism I was only rarely shown. The twinning plane is a ($i\text{-}i$, 100), the orthopinacoid, which law of twinning was first noticed by vom Rath on crystals from Switzerland. Cruciform crystals were found of almost ideal symmetry, while a few of the crystals were twinned only on one side.

A distinct but imperfect cleavage parallel to $i\text{-}\grave{i}$ (010), the clinopinacoid, was observed on several crystals, while the common basal cleavage was entirely absent. Efforts to produce it artificially were entirely unsuccessful.

It is to be noted that turnerite is described as having a perfect cleavage parallel to $i\text{-}\grave{i}$, and one less distinct parallel to the basal

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* This Journal, vol. xxiv, pp. 247–250.

plane. The fact that common monazite is described as having highly perfect basal cleavage suggests that the difference may be due to the thorium silicate often present as an impurity as shown by Penfield. It seems probable that these crystals, like the Swiss turnerite, consist of the pure phosphate of the cerium metals.

The density of monazite seems to offer a test for the presence of thorium, since that from Amelia C. H., Va., with a specific gravity of 5·30, contained 14·23 per cent ThO_2; that from Portland, Conn., specific gravity 5·20–·25, contained 8·25 per cent, and that from Burke Co., N. C., specific gravity 5·10, contained 5·49 per cent (analyses by Penfield). The best crystals of these now described have specific gravity ranging from 5·05–·09. No analysis of these crystals has yet been made, though some excellent material has been sent to Mr. Penfield for this purpose. Only about twenty good crystals were found altogether and the present indications are that the pocket is exhausted.

QUARTZ CRYSTALS WITH BASAL PLANE.—Since 1879 the writer has been much interested in the so-called "basal-plane quartz crystals" from North Carolina; his experience goes to prove the fact that genuine basal planes are very rare occurrences on this species. In the great majority of cases the planes observed have been produced by compression or juxtaposition, and when carefully measured do not meet the requirements.

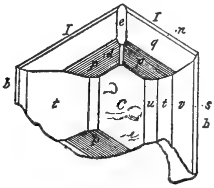
From among many crystals, appearing, when superficially observed, to possess this rare plane, I have selected two only, which, upon examination, proved to have a natural and normal development of the basal pinacoid (O). Not feeling perfectly satisfied with my determination—it being made with a hand goniometer—I sent the crystal showing the smoothest developed basal truncation to Prof. Des Cloizeaux for examination, and I add here a translation of a portion of a letter from him, dated May 8th, giving his results, for which I wish also to express my thanks. The crystals referred to were found last summer in Sharpe's township, Alexander Co., N. C.:

"Your crystal definitely disposes of the question of the basal plane on quartz, which, until now, has remained doubtful. My measurements prove that the base is quite perpendicular to the vertical axis, which we may question of many of the so-called 'basal planes' on quartz. $p(+R)\wedge a^1(O)=128°$, calc. 128° 13′. This adjustment gave an elongated reflection of which the center gave 128°. $p(+R)\wedge p$, right = 94° 12′, calc. 94° 15′. The face $b\frac{3}{2}(-\frac{1}{5}R3)$ is also present on this crystal. I have identified this face before on crystals from Wallis, and on amethysts from Brazil and Hungary." $p(+R)\wedge b\frac{3}{2}(-\frac{1}{5}R3)=147°\ 40'$, calc. 147° 39′.

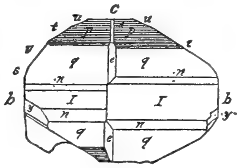
2. *A remarkable crystal of Herderite.*

The crystal here noticed was found in the early part of 1884 at the locality near Stoneham, Me., by Mr. N. H. Perry, but it did not come before me for examination until after the notices of this mineral had appeared. (This Journal, xxvii, pp. 73, 135, 229.) Excepting 3-2 (362, *x*), $i\text{-}\breve{2}$ (120, *l*) and $i\text{-}\breve{3}$ (100, *n*) all the planes observed on the American crystals occur on this crystal, and one new plane, the unit macrodome, is seen to be present, $1\text{-}\bar{i}$ (101, *d*). The pyramid 1 (111, *p*) is invariably dull and waxy looking on the crystals from Stoneham and for this reason it is distinguished from the other planes. This crystal has a diameter through the macro-axis of 25^{mm} and in point of size and general perfection is unequaled.

1.



2.



The figures represent this crystal natural size and with the natural development of the planes. Fig. 1 shows it with the brachy-axis placed vertical, while in fig. 2 the position is the normal one. The occurring planes are thirteen in number with several others slightly indicated, they are: *O* (001, *c*); $i\text{-}\breve{i}$ (010, *b*); *I* (110); $1\text{-}\bar{i}$ (101, *d*); $\frac{3}{2}\text{-}\bar{i}$ (302, *e*); $1\text{-}\breve{i}$ (011, *u*); $\frac{3}{2}\text{-}\breve{i}$ (032, *t*); $3\text{-}\breve{i}$ (031, *v*); $6\text{-}\breve{i}$ (061, *s*); 1 (111, *p*); $\frac{3}{2}$ (332, *q*); 3 (331, *n*) and 3-3 (131, *y*). This American herderite can be readily distinguished by its phosphoresence in the dark when gently heated. It exhibits under this treatment a bright orange-yellow color; amblygonite from the same locality showed a bright lavender-blue phosphoresence.

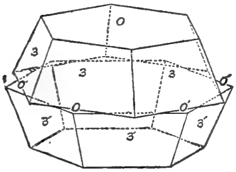
The index of refraction for this species has been determined anew by Des Cloizeaux, with results differing from those first announced. He now gives as the mean index of refraction for yellow rays: $\beta = 1{\cdot}609$; this was obtained from a small prism with an artificial face parallel to the base and a second formed by the plane *e* (302). Mr. Perry has lately found this mineral at the tourmaline locality near Auburn, Me., and a few excellent crystals were obtained there. These were announced in the Trans. N. Y. Acad. Sci. for Dec. 7, 1885, by Mr. G. F. Kunz.

In conclusion I wish to thank Mr. C. S. Bement, to whose cabinet this crystal belongs, for the opportunity of describing it.

3. *Twin crystal of Molybdenite.*

The crystal here figured was brought to my attention by Mr. C. S. Bement, who was the first to identify its twinned structure. It was found near Renfrew, Canada, along with other remarkable crystals, some of which weighed nearly a pound. One measured $3\frac{3}{4}\times 2\frac{7}{8}\times 2$ inches in thickness, while another, a thick hexagonal prism, was 4 inches long. My own measurements on this crystal and on several others from the same locality (made with hand goniometer) give the angle of the pyramid on the base as 108°, but this value at best is only approximate. These crystals and the method of twinning here figured seem to prove that molybdenite should be referred to the hexagonal system. Some few of the crystals suggest that the species may possibly be hemimorphic like greenockite, but this cannot be positively determined at present with the material at hand.

2.



4. *On the Phenacite from Florissant, El Paso County, Colorado.*

Since the original announcement of this locality,* by the writer, many additional crystals have been found by Mr. Hiestand and the best of them were sent by me to Professor Des Cloizeaux, at Paris, who has very kindly examined them. I here give substantially his results as communicated to me in a letter dated Feb. 4, 1886.

"I send a drawing of the two most remarkable of your crystals. One is a projection parallel to the base, offering an opportunity to study the new face z and the proportional development of the other occurring faces (fig. 1). The other is a perspective view of a very small but highly modified (abnormally) crystal, placed so as to show its most interesting forms" (fig. 2). The planes found by Des Cloizeaux on these interesting crystals are here given in his symbols, Miller's and Dana's, i. e.—

e^2 $(2\bar{1}\bar{1}, i)$; d^1 $(01\bar{1}, i\text{-}2)$; k $(3\bar{1}\bar{2}, i\text{-}\frac{5}{4}=b^{\frac{1}{3}}\,d'\,d^{\frac{1}{2}})$; p (100, R); b^1 $(01\bar{1}, -\frac{1}{2})$; $e^{\frac{1}{2}}$ (122, -1); e^1 $(\bar{1}11, -2)$; d^2 $(02\bar{1}, -1^3)$; z $(32\bar{1}, \frac{1}{2}^2=d^{\frac{1}{3}}\,d^{\frac{1}{2}}\,b')$ new; w $(21\bar{1}, \frac{1}{2}^3, =d^{\frac{1}{2}}\,d'\,b')$; b^2 $(021, \frac{2}{3}\text{-}2)$; y $(31\bar{1}, \frac{4}{3}\text{-}2, =d^{\frac{1}{3}}\,d'\,b')$.

Des Cloizeaux's calculated and observed angles (the latter in parentheses) on these Colorado crystals are as follows:

$d^1\,w$ adj.$=134°\,15'$ ($133°\,50'$ approx.); $d^1\,z$ over $w=123°\,0'$; $d^1\,b'$ over $w=107°\,59'$; $w\,z$ adj.$=168°\,45'$ ($168°\,50'$); $b^1\,b'$ over $O=144°\,2'$ ($144°$); $e^2\,d^2$ adj.$=147°\,51'$ (148 approx.); $e^2\,w$ over d^2 $122°\,30'$ ($123°$); $e^2\,e^{\frac{1}{2}}=107°\,40'$; e^2

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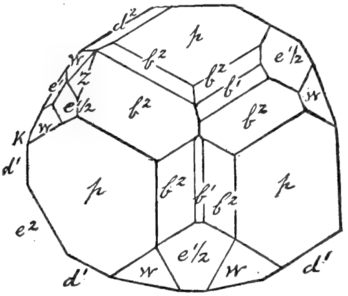
* Vol. xxix, March, 1885, p. 249.

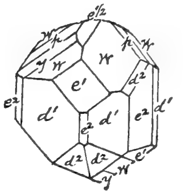
p over $e^{\frac{1}{2}}$=72° 20′ (72°); d^2 w=155° (154° 39′); w $e^{\frac{1}{2}}$ adj.=165° 10′ (165° 10′); w z over $e^{\frac{1}{2}}$=156° 32′ (156° 30′); $e^{\frac{1}{2}}$ z adj.=171° 23′ (171° 25′); $e^{\frac{1}{2}}$ p adj.=144° 41′ (144° 40′); z p adj.=153° 18′ (153° 10′); d^3 y adj.=162° 44′; d^3 z over y=150° 44′; y z adj.=168° 0′; z p opposite=138° 36′ (138° 25′).

"Colorado phenacites on amazonite (microcline) offer exactly the same association as those from the Urals. It will be noticed by reference to both the figures that, the face $w=(\frac{1}{2}3)$ is here shown holohedral, whereas, ordinarily hemihedral. The face $b^2=(\frac{2}{3}2)$ presented an anomaly on one crystal in its having the appearance of being hemihedral. This crystal also had the edge replaced between d^2 and $p=(\mathrm{R}3 \wedge \mathrm{R})$ which would have the symbol $d\frac{13}{5}$ $\mathrm{R}\frac{9}{4}$, or possibly $d\frac{8}{3}$ $\mathrm{R}\frac{11}{5}$. This crystal gave the following angles, i. e.—

1.



2.



d^2 w=153° approx.; d^2 $e^{\frac{1}{2}}$=139° 30′; w $e^{\frac{1}{2}}$=165° 30′; d^2 $d^{\frac{13}{5}}$=172° 30′, calc. 172° 36′—173°; d^2 p=150° 30′; $d^{\frac{13}{5}}p$=157° 30′, calc. 157° 27′; b^2 b^2 (hemihedral)=139° 15′."

It seems now that specimens from this locality were first shown to Mr. Whitman Cross by the finder, Mr. Hiestand, but no public announcement of their identification was made by him until after the publication of my note on the occurrence. (This Journal, March, 1885.) Among the last discoveries at this locality were some exceptional crystals, implanted on quartz crystals, that were fully 1$^{\mathrm{cm}}$ in diameter. One quartz crystal had within it a small phenacite crystal, having bright faces.

ART. XXIII.—*Turquois from New Mexico*; by F. W. CLARKE and J. S. DILLER.

AT Los Cerillos, New Mexico, about twenty-two miles southwest of Santa Fé, are mines of turquois which have been worked for centuries. The locality has been repeatedly described,* from archæological and geological points of view; but, as far as we are able to ascertain, the turquois itself has never been fully analyzed, nor has it been subjected to complete microscopic study. Having at our disposal a very full suite of specimens, collected during the summer of 1885 by J. W. Powell, Director of the U. S. Geological Survey, we have thought it desirable to investigate the subject more thoroughly, and to present our results in such form as to render them readily comparable with the published data concerning turquois from other localities.

The turquois occurs imbedded in its matrix, sometimes in nodules, oftener in seams or veins. It varies in color very widely; ranging from a pure sky-blue, through many shades of bluish green and apple-green, to dark greens which show no blue whatever. The dark green nodules often shade off to nearly white at the center, sometimes resembling in structure, as Blake has observed, certain varieties of malachite. Many of the specimens are seamed or streaked by limonite, which has been derived from accompanying pyrite; and the latter mineral occasionally is found, bright and unaltered, enclosed completely in masses of clear blue turquois.

For analysis, three samples of turquois were selected, representing as nearly as possible, the most definite types of the mineral. They may be summarily described, as follows:

A. Bright blue, faintly translucent in thin splinters.

B. Pale blue, with a slight greenish cast, opaque and earthy in luster, and of sp. gr. 2·805. Blake gives the density from 2·426 to 2·651 for the green variety.

C. Dark green, opaque.

	A.	B.	C.
H_2O	19·80	19·60	18·49
Al_2O_3	39·53	36·88	37·88
Fe_2O_3		2·40	4·07
P_2O_5	31·96	32·86	28·63
CuO	6·30	7·51	6·56
SiO_2	1·15	·16	4·20
CaO	·13	·38	undet.
	98·87	99·79	99·83

Analysis "A" is not quite complete, for enough material could not be obtained without the destruction of too valuable specimens. The silica in it was due to traces of admixed rock from which the material could not well be perfectly freed. "C," however, was free from rock; and the silica in it must be

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* W. P. Blake, this Journal, II, xxv, 227, 1858. J. S. Newberry, "Report of the Exploring Expedition from Santa Fé to the Colorado," etc., 1859; printed, 1876. B. Silliman, this Journal, III, xxii, 67, 1881.

accounted for otherwise. Silliman reports the turquois as containing 3·81 of copper, which corresponds to 4·78 of CuO; but he gives no other quantitative data.

In attempting to discuss these results it will be well to compare them with two other published analyses of turquois from different localities. First, we have the figures given by Church* for the well-known variety from Persia; and secondly, the analysis by G. E. Moore† of turquois, pseudomorphous after apatite, from Taylor's Ranch, Fresno County, California.

	Persia.	California.
H_2O	19·34	19·98
Al_2O_3	40·19	35·98
Fe_2O_3		2·99
FeO	2·21	
P_2O_5	32·86	33·21
CuO	5·27	7·80
MnO	·36	
	100·23	99·96
Sp. gr.	2·75	2·798, 2·815

These analyses, leaving temporarily out of account that of the dark-green variety, agree well with each other in their atomic ratios. Dividing the percentages by the proper molecular weights, and treating the bases together, the following ratios appear.

	Total base.	P_2O_5	H_2O
New Mexico, A,	·468	·225	1·100
New Mexico, B,	·479	·231	1·089
Persia,	·492	·231	1·075
California,	·470	·234	1·110

In each case the base stands to the acid in a ratio very slightly in excess of two to one; and that excess may fairly be accounted for upon the supposition that it represents a trifling admixture of limonite. The water is present in a proportion a little under that of five molecules to one of phosphoric acid, the variation here being due to the differences in the percentages of copper. If we calculate the amount of phosphoric acid necessary to satisfy the alumina, and then reckon the phosphate so obtained as requiring five molecules of water, we shall have left over a quantity of copper, acid, and water corresponding to a very simple formula; and the turquois will appear as a variable mixture of the two following salts:

$$2Al_2O_3 \,.\, P_2O_5 \,.\, 5H_2O.$$
$$2CuO \,.\, P_2O_5 \,.\, 4H_2O.$$

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* Chem. News, x, 290. Dana's Mineralogy, p. 581.

† V. von Zepharovich and G. E. Moore. Zeitsch. für Kryst. u. Min., x, 240.

In the Californian turquois the analytical results fit these formulæ quite sharply, and give the ratio between the two compounds as approximately four to one. The first formula may be regarded as that of normal turquois, and may be written in rational form, halved, as

$$Al_2HPO_4(OH)_4.$$

The copper salt, to which the mineral owes its color, is to be considered merely as an impurity; a view which is emphasized by the analysis of the dark-green turquois, "C." In the latter case the same ratios apply, modified by the presence of silica, which is nearly sufficient to form with the copper a normal metasilicate, similar to if not identical with chrysocolla. This silicate, with whatever blue tinge of color it might have, affected by the yellow or brown of the iron present, probably gives the turquois its green hue. It is exceedingly probable that the purity of tint in gem turquois is due to the copper salt alone; and that degradations of the color towards green are ascribable to admixture of salts of iron. It is noteworthy that, of the three turquoises analyzed, the bluest contains the lowest percentage of copper. This could hardly be the case were not the colors of the other samples modified by some impurities: and compounds of iron would naturally produce an effect in the observed direction.

Sections of the three varieties of turquois were studied under the microscope, and found to be of essentially the same character. Although deeply colored in the hand specimens, the thin sections appeared almost clear and transparent. Between crossed nicols the deep blue and green forms were seen to be composed of minute grains, or short, thick fibers; but in the paler varieties the fibrous structure was more pronounced. The optical properties of both grains and fibers are the same throughout. They are all weakly doubly refracting, but have a rather high refractive index. The finely granular portions have a pale bluish aggregate polarization, less intense than that of chlorite; but when the mineral is distinctly fibrous it polarizes like some forms of serpentine, with light colors of the first order. The fibers are generally somewhat bent and interwoven, but lie approximately in the same direction. Each fiber becomes dark when parallel to the principal section of either of the crossed nicols, indicating that they must crystallize according to either the quadratic, hexagonal, or rhombic system, instead of in one of the inclined systems as was the case with the fibers studied by Bücking* in the turquois of Fresno County, California.

A section was prepared of a distinct vein of pale-green tur-

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* See paper by v. Zepharovich and Moore, previously cited.

quois, which showed that the fibrous structure is directly across the vein perpendicularly to its walls. Small fissures, running into or across the veins, have the fibers of turquois arranged perpendicularly along their sides just as serpentine arranges itself along fissures in olivine. Sometimes the fissures are minute and curved; but the resulting arrangement does not simulate the radial fibrous or spherulitic structure described by Bücking* as found in the turquois of California, Nevada and elsewhere.

The perpendicular arrangement of the turquois fibers along fissures crossing the vein, indicates that the mineral may have been derived from the alteration of another substance with which the vein was formerly filled. We would suppose, of course, that the original vein material was itself a phosphate; and the only one after which turquois is known to be pseudomorphous is apatite; a species which not infrequently occurs in veins. The opinion that the turquois has resulted from such an alteration is favored by the presence of other alteration products, to be noted in considering the composition of the country rock in which the turquois is found. It is also suggested by Hermann's analysis of blue oriental turquois, in which the equivalent of 3·41 per cent of calcium phosphate was actually determined.†

The rock in which the veins of turquois occur is described by Blake as "a granular porphyry, yellowish, gray, or white in color, porous and earthy in texture. It decomposes rapidly by weathering, and very much resembles a sandstone." In the collection made by Major Powell there are several good examples of the rock penetrated by the turquois. It is a fine-grained, reddish, feldspathic rock, mostly fresher than that described by Blake, and it has a microgranitic aspect. It contains numerous particles of biotite and pyrite, with stainings of oxide of iron. The hand specimens look as though they had been crushed, and the fissures thus formed so filled as to produce irregular veins and nodules. The veins are small, and mostly composed of turquois, in which are imbedded a few scales of biotite, particles of pyrite, and considerable quartz and oxide of iron. Scales of biotite are found abundantly in the iron-stained cavities, as well as in the solid portions of the rock. Some specimens of rock, containing much pale blue turquois of earthy texture, have been completely kaolinized, and a partial analysis of the kaolin gave the following results:

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* Zeitsch. für Kryst. und Min., ii, p. 163.

† See Dana's System of Mineralogy, p. 581.

H_2O	12·88
SiO_2	52·38
$Al_2O_3+Fe_2O_3$	33·49
P_2O_5	none
MgO	1·17
CaO	trace
	99·92

Although the mineral itself was white, the alumina from it was distinctly reddish with the iron.

Under the microscope the rock is seen to be composed chiefly of feldspar, with a considerable amount of biotite, epidote, pyrite and limonite, and some amorphous substance. It is somewhat micrognanitic in structure, and the irregular, interlocking grains of feldspar vary in size from ·01 to ·8^{mm} in diameter. Most of them are considerably kaolinized, so as to appear cloudy in ordinary light; but between crossed nicols the original outlines of the grains become more distinct. Their optical properties indicate that the feldspar is orthoclase; an opinion which is fully borne out by the subjoined analysis of the rock, which shows a remarkably large proportion of potash.

H_2O	3·28
SiO_2	56·68
Al_2O_3	16·62
Fe_2O_3	6·50
P_2O_5	·73
MgO	·79
CaO	·59
CuO	trace, undet.
MnO	1·02
FeS_2	2·21
K_2O	11·18
Na_2O	1·03
	100·63

The porphyritic crystals are generally Carlsbad twins with irregular outlines. There are occasionally small grains of fresh, transparent plagioclase, which has evidently resulted from alteration.

The biotite of the rock occurs in noteworthy quantities, but is very unequally distributed. It is frequently aggregated in groups of scales, and may be seen most abundantly in small cavities. It sometimes occurs intimately associated with the turquois, but unlike the latter it is one of the primary minerals. The small quantity of quartz present is a secondary product, so intimately associated with turquois as to suggest their genetic connection. Pyrite is scattered rather uniformly throughout the rock in small cubical crystals easily seen in the hand specimen. They are sometimes altered to limonite, but in other cases they have been completely replaced by pseudomorphs of epidote. The specimen of rock which was subjected to analysis probably contained an amount of pyrite rather greater than the average.

One of the most important constituents of the rock, because of its very close association with the turquois, occurs in the form of bright yellow grains. They are not distinctly pleochroic, but have a high refractive index, with strong double refraction, and give brilliant aggregate polarization. The particles are usually very small, and grouped together in irregular compound grains so as to suggest nothing of crystallographic form. In several cases, however, elongated simple grains show inclined extinction; which indicates that the mineral must be either monoclinic or triclinic in crystallization. Judging not only from the properties enumerated, but also from the percentage of lime in the rock, this mineral is in all probability epidote. It is evidently connected genetically with the turquois, for it is almost uniformly found upon the border of the latter, and is most abundant in its neighborhood.

Concerning the origin of the turquois-bearing rock, it may be stated that Professors Newberry and Silliman, both of whom studied it in the field, regard it as eruptive, and probably of Tertiary age. The occurrence of this veritable orthoclase rock in the West is of special interest from the facts disclosed by recent investigations that in many of the rocks previously described as trachytes the predominating feldspar is plagioclase.

The very small size of the veins and their limited distribution show that the turquois is of local origin, and emphasizes the idea that it has resulted from the alteration of some other mineral. In addition to the evidence already cited to show that the turquois has been derived from apatite, we have the fact that epidote, a lime-bearing mineral, is present as a secondary product. The oxidation of pyrite may have had something to do with initiating the process of alteration, and the alumina of the turquois was probably derived from decomposing feldspar. The latter suggestion was made by Silliman, who also examined microscopic sections of the rock, and reported apatite as present. No apatite, however, could be seen in the specimens examined by us. A search for it at the locality would certainly seem to be desirable.

U. S. Geological Survey, Washington, April, 1886.

ART. XXV.—*On the Electrical Resistance of Soft Carbon under Pressure;* by T. C. MENDENHALL.

A PAPER by the writer on "the influence of time on the change in the resistance of the carbon disk of Edison's Tasimeter," was published in this Journal in July, 1882. The object of the paper, as its title indicated, was to present the results of some experiments with the carbon disk which appeared to show that, when pressure was applied, the entire diminution of resistance did not take place at once, but that the reduction continued with diminished rapidity through a considerable period of time. At the conclusion of the paper brief reference was made to investigations of the same subject by Mr. Herbert Tomlinson and by Professors Sylvanus P. Thompson and W. F. Barrett.

Only the conclusion reached by some of these physicists was at that time known to the writer, their verdict being that the observed diminution of resistance was really due to the better surface contact of the electrodes and not to any actual change in the specific resistance of the carbon itself.

The last paragraph in the paper contains the following: "without knowing anything about the nature of these experiments the writer desires to record his belief that this theory does not entirely account for the facts stated above."

This, certainly not too rash, declaration of belief in a true pressure effect was the subject of decidedly unfavorable criticism in the columns of one or two European scientific journals; and in this Journal of December, 1882, Professor Sylvanus P. Thompson published an article entitled "Note on the alleged change in the resistance of carbon due to change of pressure," which was an exceptionally severe criticism of the previous paper by the writer. In this article Professor Thompson refers to the investigations of Mr. Tomlinson, Professor Barrett and himself and also to experiments made by Professors Naccari and Pagliani and Mr. Conrad W. Cooke, and he declares that, with the exception of Professor Mendenhall, all who have investigated the point are agreed in their verdict "that this alleged effect was due not to any change in the specific resistance of carbon, but to better external contact between the piece or pieces of carbon and the conductors in contact with them." The truth of this statement is the question at issue. It may be well to remark, however, that although Professor Thompson makes this assertion in December, Mr. Tomlinson had shown, nearly a year earlier, in a paper presented to the Royal Society, on the 26th of the previous January, that the electrical resistance of hard carbon was diminished by pressure. The amount of the diminution is small, however, and he afterwards expresses the opinion that in such instruments as the microphone transmitter, the greater portion of the observed diminution in resistance is due to variation in surface contact.* Mr. Tomlinson's experiments were made with hard carbon, similar in character to that made use of in experiments to be described presently.

In the summer of 1884, the writer communicated, to the American Association for the Advancement of Science, a brief account of experiments which satisfied him that the opinion which he had previously expressed concerning the nature of the phenomenon was unquestionably correct. Within the past year the subject has been taken up again, and by means of improved methods and instruments, all doubts seem to have been removed.

Innumerable experiments made by physicists of many countries have established, beyond question, the fact that the electrical properties of matter are modified by stress and strain. In carbon the effect of pressure is to diminish resistance. For hard carbon this was established by the investigation of Mr. Tomlinson. In compressed lampblack, as seen in Edison's disks, the effect is very great and that this is for the most part a true pressure-effect is proved, it is believed, by the experiments about to be described.

In the beginning it was desirable to determine, roughly, the magnitude of this effect in the case of hard carbon. For this purpose a copper plated rod, such as is used in the arc lamp, about 12^{cm} in length and $1·5^{cm}$ in diameter, was selected and its ends were ground flat at right angles to its axis. The plating was then removed, except that a band about $·5^{cm}$ in width was left near each end of the rod. Two cork rings $1·5^{cm}$ thick were fitted to the rod, after which they were tunneled out on the inside, and a hole was made in each so that when they were in place over the copper bands, and mercury was poured in, it would flow around the ring tunnel and make a contact with the carbon as satisfactory as could be desired. The ends of the rod were protected by thin plates of vulcanite, and it was placed between the jaws of a vise. The current from a battery of two or three gravity cells was passed through the rod by plunging wires into the mercury cups formed by the corks. By this arrangement it was possible to apply pressure at the ends of the rod without in any way influencing the contacts through which the current passed.

The terminals of a reflecting galvanometer whose resistance was about 5000 ohms were also introduced into these mercury

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* Nature, March 16, 1882.

cups and enough additional resistance was introduced to make a convenient deflection of the spot of light upon the scale. When all was adjusted and the spot of light was at rest, the pressure was applied by turning the handle of the vise. In every instance the deflection decreased showing diminished resistance. This effect was not due to the heat produced by compression as experiment proved that cause to be inadequate. It was found to be necessary to make the carbon rod decidedly warm to the touch in order to lower the resistance by the same amount, besides the effect was not transient as would have been the case if it had been due to the change in temperature. It was also found that compression at right angles to the direction of the current produced a similar effect, but less in magnitude. These facts had been already announced by Mr. Tomlinson.

These experiments with hard carbon or with other rigid bodies are comparatively easy, as there is no difficulty in applying the pressure independent of the contact surfaces, so that possible variation of the latter need not be considered. Unfortunately it appears to be quite impossible to secure this arrangement in the examination of soft carbon. It cannot readily be obtained in forms different from the small disk or button in which it originally appeared, and it is so fragile that it requires the most careful manipulation. Under these circumstances the only thing to do is to secure the best possible surface contact of the poles to begin with. Perhaps the ideal arrangement would be a disk with its two opposite faces electro-plated with copper, through which a contact with mercury can be secured. The electro-plating of two opposite faces of a disk of compressed lamp-black is a work of extreme difficulty and so far as known to the writer has not yet been accomplished, although he is greatly indebted to Mr. Edison for a serious and persistent effort to secure this result, none the less appreciated because, owing to the extremely fragile character of the disk, it proved to be unsuccessful.

It was therefore necessary to depend upon the contact of mercury with the surface of the carbon itself. As this was the contact employed by Professor Barrett in the experiment which Professor Thompson considered "crucial," its use can hardly be objected to in this instance.

The arrangements for the test of the soft carbon were as follows: two glass tubes about 20^{cm} in length were bent at one end into a quarter of a circumference, so that when the two were joined and the straight branches of the tube were in a vertical position the appearance was that of the letter "U," the height being about 15^{cm}. Near the lower end of each a short tube was sealed in, over which rubber tubing could be passed, and at the lower part of the curve, in each, a platinum wire was passed through and sealed. The ends of the tubes were ground flat, and they were mounted in such a way that while one was fixed in position, the other could be moved toward or away from it in one plane, and so that the ground ends of the curved parts were always exactly opposite to each other. The movable tube was then taken from its place, the ground edge of its curved end was coated with glue, and it was carefully brought down upon the upper surface of a carbon disk which rested in a horizontal plane. The glue causing the disk to adhere to the tube, the latter could then be secured to its sliding stand, ready to move into place. The ground edge of the fixed tube was now coated with glue, after which the movable tube holding the carbon disk was gently moved up until the disk pressed against the end of the other tube, the glue forming the junction. In this way a carbon wall or partition was formed between the two halves of a "U" tube. When the glue had hardened, mercury was introduced on both sides to a height sufficient to entirely cover the faces of the carbon disk. The current was introduced through the platinum electrodes which plunged into mercury cups on either side.

In some of the earlier experiments variations of pressure were produced by the addition of mercury to the two branches of the tube, but vastly better than this was the method latterly used in which the pressure of air was substituted for that of mercury. Glass plates were sealed on the open ends of the two upright branches thus inclosing a space on each side, except at the small side tubes to which short pieces of rubber tubing were attached. These were joined by means of a "T" tube so that equality of pressure on both faces of the disk was secured.

The circuit consisted of the battery, the disk and an additional resistance varying from 3 ohms to 10 ohms for purposes of comparison. The electric ends of the disk and of the resistance were joined to a specially arranged key, by means of which either could be connected with the terminals of a reflecting galvanometer whose resistance was about 7000 ohms. By means of the deflections of the needle of this galvanometer, the resistances were compared and variations noted, the arrangement being substantially the same as that previously used in the experiments with hard carbon. A pressure gauge, sometimes of water, sometimes of mercury, was attached to the apparatus to indicate variations in pressure, and these variations were generally produced by blowing from the mouth into a rubber tube about two meters in length. Very many experiments were made, all without exception, showing great diminution in the resistance of the disk by increase of pressure, and it will be sufficient to quote a few of the results.

The disk is sufficiently sensitive to show very slight changes in atmospheric pressure. On closing the open end of the rubber tube, and slightly pressing any part of it between the thumb and finger, the spot of light instantly moved, showing decrease of resistance. A pressure measured by 5^{mm} of water produced a decided effect. The resistance of the disk, with its mercury and platinum wire connections, under ordinary conditions was slightly greater than 6 ohms. A pressure measured by 5^{cm} of mercury instantly reduced it to less than 3 ohms. If the pressure was maintained, a slow fall of resistance continued for a long time, as found in the previous investigation of the subject. If the initial pressure was small, the recovery would be instantaneous on its removal, but if it was large, so as to greatly reduce the resistance, it was found that the recovery would not be complete on the withdrawal of the pressure, sometimes falling short as much as ten per cent, after which a slow rise would take place. This result is not quite in agreement with the statement made in the first paper upon this subject, which was based, however, upon a much less satisfactory series of experiments.

An examination was made of the effect of the strength of the current upon the resistance of the disk. The weakest current used was a little less than ·001 ampere, and the strongest was about ·37 ampere, so that one was approximately 400 times the other. Throughout this range no sensible differences in the resistance of the disk were observed, the agreement at the two extremes being within the errors of measurement. Under all conditions the effect of variations of pressure was the same.

The faces of a soft carbon disk are always smooth and polished; the surface of hard carbon on the contrary is generally more or less rough and irregular. It would appear, therefore, that, if the reduction of the resistance of soft carbon by increase of pressure is due to better surface contact, this reduction of resistance should be much more marked with hard than with soft carbon. Experiments already described showed that the effect of pressure on hard carbon was very small; so small, in fact, that the pressure of a few centimeters of mercury would hardly produce a sensible effect.

The substitution of a disk of hard carbon for the soft, in the apparatus described, ought to show then whether any considerable part of the resistance variations observed could be attributed to variation of contact between mercury and carbon. A disk of hard carbon similar in dimensions to the soft disk previously employed was accordingly inserted between two similarly arranged tubes. The result of this experiment was to show, as had been anticipated, a small decrease of resistance when the pressure was increased. A pressure of about 7^{cm} of mercury reduced the galvanometer deflection from 36 to 35 divisions of the scale. This indicates a change of less than three per cent, resulting from a pressure which with the soft disk lowered the resistance by more than sixty per cent. There can be little doubt that this small reduction is due almost entirely to better surface contact produced by pressure.

Throughout all of the experiments with soft carbon, it exhibited more or less irregularity in its behavior. The application of a pressure very largely in excess of the maximum referred to above would sometimes result in a permanent reduction of the resistance of the disk, indicating that a permanent set had taken place. By the exercise of care, however, what may be called the "normal" resistance may be maintained fairly constant for a considerable length of time.

Conclusions.—When carbon is prepared in the form of compressed lamp-black, its electrical resistance varies greatly with the pressure to which it is subjected. A small part of this variation is doubtless to be attributed to change in surface contact between the carbon and the electrodes through which the current is introduced, but by far the larger part (provided any effort is made to secure good surface contact) is due to a real change in the resistance of the carbon itself. The resistance of carbon in this condition is fluctuating and uncertain to a degree that seems to prevent its use as a factor in any device for the accurate measure of pressure.

ART. XXVI.—*Comparison of Maps of the Ultra Violet Spectrum*; by EDWARD C. PICKERING.

ONE of the first accurate maps of the ultra-violet portion of the solar spectrum was made in 1873 by the late Dr. Henry Draper. A photograph of a normal diffraction spectrum was prepared and copies printed by the Albertype process. A wide distribution was given to this work, which was published also in this Journal, cvi, p. 401. This map extended from 345 to 394, adopting as a unit the millionth of a millimeter. The scale was such that one unit equaled $0{\cdot}31^{cm}$. Soon after, M. Cornu published in the Annales Scientifiques de l'Ecole Normale Supérieure, III, 421, a steel engraving representing the region extending from 343·5 to 412·5. The map was intended as a continuation of the work of Ångström and was on the same scale, one unit equaling 1^{cm}.

The recent publication of a photograph of the solar spectrum by Professor Rowland furnishes a convenient standard with which these maps may be compared. The improved apparatus and enlarged scale of Professor Rowland's work rendered it probable that its accidental errors would be unimportant in the present comparison, especially as the measures are only to be carried to hundredths of a unit. As a check upon its systematic errors a comparison has been made with the investigations of Dr. Müller and Dr. Kempf in the Publicationen des Astrophysikalischen Observatoriums zu Potsdam, V. Three hundred lines were measured between the limits of 686 and 389. About two hundred of these are contained in the region covered by Professor Rowland's map. A comparison of a number of them indicate that the accidental errors are very small. The width of the bands or groups of lines into which many of the lines are resolved renders it largely a matter of judgment where the center should be taken. The systematic differences are about 0·01, or more strictly the wave-lengths according to Rowland exceed those of Müller and Kempf by about one eighty thousandth part. The region 588 to 590 occurs on four of the strips of Rowland's map. The positions of forty-five of the lines contained in this region were estimated on all four strips and indicated corrections of +·0007, +·0007, −·0009 and −·0004 respectively. These quantities are probably due to accident. They are inappreciable by the method of measurement employed, as they would not exceed one five hundredth of an inch on the map.

The specimen of Dr. Draper's map with which the comparison was made was not a proof impression, but was taken from a copy of this Journal. The positions of seventy-six lines were read, estimating the divisions to tenths by the aid of a reading glass having a focal length of about 10^{cm}. Preference was given to well defined lines, a few bands with hazy edges being omitted. The corresponding positions of these lines were then read from Professor Rowland's map, estimating the tenths by the unaided eye. The differences were arranged in groups as shown in table I, according to their wave-length. Each group extends over one unit, the middle points having the values given in the first column of the table. The number of lines contained in the group is given in the second column, and the mean of the residuals, Draper *minus* Rowland, in the third column. The fourth column gives the results of a similar comparison with the map of Cornu. The same lines were used except that having a wave-length of 393·76, which is not given on Cornu's map. Some uncertainty exists regarding three or four of the other lines, where the engraving does not agree with the photograph. No large residuals are thus introduced, since lines in the right place are selected even if the intensity is incorrectly represented.

TABLE I.

λ	No.	D−R.	C−R.
372·0	3	+·037	−·087
373·0	5	+·032	−·070
374·0	3	+·037	−·077
375·0	3	+·023	−·070
376·0	3	+·003	−·060
377·0	2	+·005	−·075
378·0	3	+·007	−·093
379·0	3	−·003	−·097
380·0	3	−·007	−·023
381·0	1	+·020	−·070
382·0	3	−·017	−·073
383·0	5	−·030	−·084
384·0	2	−·030	−·090
385·0	6	−·027	−·102
386·0	5	−·026	−·086
387·0	3	−·027	−·133
388·0	2	−·045	−·150
389·0	3	−·067	−·153
390·0	6	−·062	−·128
391·0	5	−·042	−·084
392·0	3	−·057	−·107
393·0	2	−·080	−·100
394·0	2	−·075	−·100

The results of table I are combined in table II, where each group extends over five units. An inspection of these tables shows that the maps differ systematically, the wave-lengths according to the map of Dr. Draper being too great for the lines of short wave-lengths. The relation is very closely represented by the formula,

TABLE II.

λ	No.	D−R.	C−R.
375·0	16	+·023	−·070
380·0	13	−·003	−·079
385·0	21	−·028	−·097
390·0	19	−·055	−·119

$$D - R = \cdot 0052\,(379{\cdot}6 - D),$$

in which D and R represent the wave-lengths according to Dr. Draper and Professor Rowland respectively.

Representing by C the wave-lengths according to Cornu, we have in like manner the correction,

$$C - R = \cdot 003\,(351{\cdot}7 - C).$$

Where the wave-lengths are only carried to hundredths of a unit the corrections may be more readily applied by means of table III, which gives the limits within which each correction of one hundredth of a unit is to be applied. The first part of the table gives the corrections of Dr. Draper's map, the second the corrections of M. Cornu's map.

TABLE III.

Limits.	Corr. Dr.	Limits.	Corr. Dr.	Limits.	Corr. C.
370·04 to 371·95	+·05	382·48 to 384·39	—·02	370·00 to 373·33	—·06
371·96 to 372·87	+·04	384·40 to 386·31	—·03	373·34 to 376·66	—·07
372·88 to 374·79	+·03	386·32 to 388·23	—·04	376·67 to 379·99	—·08
374·80 to 376·71	+·02	388·24 to 390·15	—·05	380·00 to 383·33	—·09
376·72 to 378·63	+·01	390·16 to 392·07	—·06	383·34 to 386·66	—·10
378·64 to 380·55	·00	392·08 to 393·99	—·07	386·67 to 389·99	—·11
380·56 to 382·47	—·01	394·00 to 395·91	—·08	390·00 to 393·33	—·12

As an example of the use of this table, if a line on Dr. Draper's map has a wave-length of 371·95, its true wave-length may be assumed to be 372·00. In like manner 390·00 becomes 389·95. The same readings on Cornu's map would become 371·89 and 389·88.

Applying these corrections to the wave-lengths derived from the map of Dr. Draper, we obtain results which agree very closely with those given by Professor Rowland. The mean difference for the seventy-six lines compared was 0·012, corresponding to about one eight-hundredth of an inch upon the Draper map. Probably a remeasurement of the larger differences would still further diminish the average value. No differences were rejected, the two largest having the values 0·05 and 0·06. The mean difference of 0·012 gives a probable error of 0·010, which includes the errors of the two readings and the accidental errors of both maps. We may therefore assume that that the probable error of a wave-length derived from the map of Dr. Draper will not exceed one one-hundredth of a unit if the correction given above is first applied. The minuteness of this quantity is a good illustration of the accuracy attainable from a record obtained automatically by photography. The wave-lengths given on the map of Cornu when corrected in the same way give an average deviation of 0·025, equal to about one one-hundredth of an inch on the map. This is in accordance with the belief of Cornu himself that the probable error of the drawing would not exceed 0·03.

ART. XXVII.—*On two hitherto undescribed Meteoric Stones;* by EDWARD S. DANA and SAMUEL L. PENFIELD.

1. *Meteorite from Utah.*

IN the summer of 1869, the meteoric stone now described was found by Mr. Clarence King in Utah, on the open prairie between Salt Lake City and Echo. It was given by Mr. King to Professor Brush and he presented it to the Yale College Collection. Nothing is known in regard to the circumstances or time of its fall; in that dry climate it may well have lain exposed on the surface of the ground for a long time without disintegration, especially as it was well protected by its crust.

The weight of this stone is 875 grams; it is oblong in shape, about 12^{cm} long, and 9^{cm} in its greatest width; one edge is sharp and wedge-like, and one end is relatively sharp, the other rounded. The surface is comparatively smooth and shows only a few broad and shallow pittings. A uniform crust, smooth except for minute angular elevations on certain portions and not very thick, covers it almost completely. The color of the crust is reddish black, in consequence of the partial rusting of the fused material. A small portion of the mass has been broken from one end to give material for study.

The interior of the stone is of a dark bluish gray color, distinctly mottled by its chondritic character, and showing a rather large proportion of iron irregularly distributed through it, with minute patches of troilite. The small portions of the interior of the stone which had been exposed are much stained by the oxidation of the iron, but this change has penetrated comparatively little into the mass, and the stone as a whole is exceptionally hard and firm. The nature of the mineral substances which, together with the metallic parts, make up the mass can be only imperfectly made out by mere macroscopic examination; thin sections, however, under the microscope show this very satisfactorily. The olivine is the most prominent constituent. This appears frequently in spherules or "chondrules" of the size of very small shot; these are made up of a multitude of individual grains having distinct rounded outline and each with its own optical orientation. These granular chondrules are sometimes enclosed by an iron border, and as the grains of olivine are fresh and clear and give brilliant polarization colors, they form very beautiful objects under the microscope. The separate grains in these cases are closely packed together, but sometimes show a little intermediate glassy matter. The olivine also appears in relatively large fragments, much fractured, but showing by the common optical orientation that all belongs to a single individual. Still again the olivine is seen in chondrules which have a distinct coarsely fibrous structure in consequence of the inclusions of dark-colored glass.

The bronzite (enstatite) appears in irregular crystal fragments scattered through the mass. Also in chondrules with fine fibrous structure usually eccentric; these have sharp angular outlines in many cases and appear to be but fragments of the original spherules—in this as in some other respects the stone has a marked brecciated character. To the bronzite also are to be referred occasional large spherules having a coarsely fibrous or columnar structure, the fibers lying in several directions within the limits of the same individual.

Plagioclase feldspar seems to be sparingly present in crystalline fragments, showing distinct, though not sharp, twinning structure. Especial interest attaches to this constituent of the stone because it shows most clearly the brecciated character just alluded to. One piece for example has been broken transversely a number of times and then cemented by the groundmass so that it still preserves in general its original outlines though made up of separate sections. This feldspar is rich in black inclusions lying parallel to the twinning lines. A number of patches of an isotropic mineral, which is probably to be referred to maskelynite, were also observed.

The specific gravity of this meteorite was found to be 3·66. A careful chemical analysis (Penfield), gave the following results. It was divided in the first place into the nickeliferous iron 17·16 per cent and the mineral part including the troilite and silicates 82·84 per cent.

The analysis of the iron yielded:

Fe	91·32
Ni	8·04
Co	0·60
Cu	0·04
	100·00

The mineral portion was divided into:

Soluble in HCl	Troilite Fe (Ni) S	6·70 with NiS=0·62
	Silicates	48·85
Insoluble in HCl including chromite		43·97
Water		1·14
		100·66

The analyses of the soluble and insoluble portions gave further:—

	Soluble in HCl.		Insoluble in HCl.	
SiO_2	19·70	40·33	24·11	54·83
Al_2O_3	0·25	0·51	2·12	4·82
FeO	10·42	21·33	3·80	8·64
MgO	17·17	35·15	10·80	24·56
CaO	0·81	1·66	1·47	3·34
Na_2O	0·16	0·33	0·87	1·98
K_2O	0·02	0·04	0·05	0·12
P_2O_5	0·32	0·65	----	----
Chromite	----	----	0·75	1·71
	48·85	100·00	43·97	100·00

The molecular ratio of the silica to bases in the soluble portion is 1:1·72, so that besides the olivine the glassy portion is probably here included. The composition of the insoluble part implies that it is made up largely of bronzite with a little plagioclase. Among the stones in the Yale College collection that from Chantonnay seems to bear the closest resemblance to this new stone.

2. *Meteorite from Cape Girardeau, Missouri.*

This Missouri meteorite has waited just forty years for public description. It became the property of the Yale Museum several years ago, having been purchased from Dr. Otto Lugger of Baltimore, to whom we are indebted for the facts in regard to its history. The stone was obtained by Dr. Lugger when he was residing in St. Louis, about the year 1875, from an acquaintance, by the name of Padberg, whom he had employed to collect for him various objects in natural history, minerals and so on. According to Padberg's statement, the meteorite had formed part of his mineral collection since 1847. It was provided with a label which stated that it fell at 3 o'clock on the afternoon of August 14th, 1846, accompanied by a loud report, upon a small farm belonging to an Englishman by the name of William Free. This farm lay some 7½ miles south of Cape Girardeau in southeastern Missouri. The meteorite was given to Padberg by Free in 1847. It was stated further that the meteorite broke upon its fall into three pieces, two of which form the mass here described, and the third was polished and presented by Dr. Lugger three years ago to Professor Uhlberg.

The account of the history of the stone, of which the above is an abstract, is so complete and circumstantial as to make it appear worthy of confidence, notwithstanding the many years which have passed since the stone fell.

The stone, when it became the property of the Museum here, consisted of two parts weighing together 2,058 grams. These two portions fitted closely together, and the fractured surface between them was fresh except for the oxidation of the iron. The general shape of the stone is roughly rectangular with dimensions of 12×10×10 centimeters. The surface is smooth with no sharp edges nor angular projections. On one side, the crust, which is rather thick, shows with remarkable distinctness the lines of flow diverging from what was probably the projecting point in its flight through the air; on what was presumably the rear side the crust is thicker, rather rough and somewhat cellular or slag-like. One portion of the surface is simply blackened over without having a distinct crust, as if a part had been broken off shortly before it struck the ground. The general color of the fresh surface is light gray except as it is stained by the rusting of the iron; this oxidation has proceeded rather far, as might have been anticipated, and indeed the appearance of some portions suggests that there may have been present also some deliquescent compound (e. g. iron chloride). The mass as a whole is somewhat porous and easily fractured.

The metallic particles, which have mostly a bluish tarnish, are scattered very uniformly through the whole mass. The chondritic character is distinct though not strongly marked, yellowish white spherules of olivine, and others of a dark gray (bronzite?) are sparingly scattered through it; for the most part it appears to be granular crystalline.

In the sections examined under the microscope the olivine is seen in granular form, not often distinctly grouped in chondrules; the bronzite also in longitudinal fragments. The dark gray chondrules have an indistinct fibrous eccentric structure and act rather feebly on polarized light—they may be also bronzite. The feldspar is not particularly distinct, although occasional patches of a dull gray in polarized light probably belong here. Glassy matter was not distinctly observed.

The specific gravity of a fragment of the stone was found to be 3·67. The chemical analysis (Penfield) showed a relation of native iron to troilite and silicates very near that of the Utah meteorite, namely, 17·90 to 82·10 per cent.

The analysis of the iron gave:

Fe	91·93
Ni	7·39
Co	0·63
Cu	0·05
	100·00

The analysis of the latter portion yielded:

Soluble in HCl	Troilite	6·95
	Silicates	42·68
Insoluble in HCl, including chromite		50·19
Water		0·58
		100·40

The soluble and insoluble parts gave further:

	Soluble.		Insoluble.	
SiO_2	15·50	36·32	28·00	55·79
Al_2O_3	tr.	----	2·78	5·54
FeO	9·52	22·31	3·97	7·91
MgO	17·17	40·23	11·87	23·65
CaO	----	----	1·68	3·35
Na_2O	0·12	0·28	0·93	1·85
K_2O	0·02	0·04	0·12	0·24
P_2O_5	0·35	0·82	----	----
Chromite	----	----	0·84	1·67
	42·68	100·00	50·19	100·00

The composition of the first portion corresponds very closely to a ferruginous olivine, the ratio of silica to bases being 1:2·17. The insoluble part is evidently for the most part bronzite with probably a little feldspar to which the alumina and soda and most of the lime belong. This stone belongs to rather a common type of meteorites, the light gray chondrites; there is, however, no stone in the Yale College collection from which it could not be at once distinguished.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On a Density Pipette.*—AMAT has devised a modified form of pipette, by which the density of a liquid may be approximately determined. It consists of a straight glass tube, graduated, to the upper end of which is attached laterally a U tube also graduated on both legs. The standard liquid is placed in this U tube and by means of a rubber spherical cap on the upper end of the pipette, the given liquid may be drawn into the main tube. Noting the height of this column and comparing it with the difference of level in the standard columns, the specific gravity of the given liquid may be obtained in terms of the standard. A small correction must be made for capillarity at the narrowed end of the main tube. The results given agree with those made with the specific gravity bottle, to the second decimal place. The liquid in the pipette is allowed to flow out by removing a cork from a lateral opening near the top.—*Bull. Soc. Ch.*, II, xlv, 482–484, May, 1886. G. F. B.

2. *On Water of Crystallization.*—PICKERING has discussed the nature of the water of crystallization in salts and the relation which this water bears to the salt with which it is associated. He concludes (1) that the theory that the sulphates contain either one or two molecules of "constitutional" water finds no confirmation whatever in general considerations as to their formation, properties, composition and analogies with other salts; (2) that the most decisive evidence as to whether a given salt is an "ortho" salt or a basic salt is afforded by the nature of the metals which form such salts, and by ascertaining whether it displaces the hydrogen atoms singly or in pairs. Those metals which displace "acid" hydrogen most energetically are the ones which exhibit least tendency to form basic salts; (3) that although the heat of hydration of a salt indicates that the lower hydrates are generally more stable than the higher ones, it gives no information whatever as to whether the various water molecules in any particular hydrate are all similarly combined or not; (4) that no information on this point is afforded by the different temperatures at which the water molecules are evolved; (5) that

experimental evidence, no less than general considerations, show that the water molecules in a lower hydrate are affected by the addition of more water. The higher hydrate does not *contain* the lower one; (6) the displacement of one of the water molecules in the magnesian sulphates by K_2SO_4 affords no grounds for the supposition that the one displaced differed in any respect from the others. The physical properties of the resulting double salt afford a strong argument in favor of the displaced molecule being water of crystallization only; (7) that the specific heats of hydrated salts throw no light on the nature of the different water molecules; (8) that experiments with the solid hydrated sulphates of the magnesian metals show that the volume of the water in the lower hydrates is relatively less than in the higher hydrates. But the difference is not such as would indicate any difference in nature of any of the various hydrates, and certainly affords no information as to the volumes of the individual water molecules in any particular hydrate; (9) that the volume of dissolved salts may show that one molecule of water in these magnesian sulphates differs from the rest; but the data available are at present too meager to warrant any definite conclusions being drawn. At any rate, whatever the difference may be, it is of exactly the opposite nature to that which would be exhibited if it were water of "constitution;" (10) that with the exception of this last-mentioned fact, which can at present be regarded as a possibility only, we have no grounds for supposing that the various water molecules in a hydrated salt are not all combined in a similar manner, and do not all occupy exactly the same position with regard to the salt-nucleus; that in short a hydrated salt is not a symmetrical substance. At the same time it must be admitted that we have no positive evidence to show that it is symmetrical, and we must regard it as such provisionally only, till some unquestionable evidence in favor of or against this view be forthcoming.—*J. Chem. Soc.*, xlix, 411–432, June, 1886.

G. F. B.

3. *On the Fulminating silver of Berthollet.*—RASCHIG has studied the compound obtained by Berthollet nearly a hundred years ago by the action of ammonia upon silver oxide. For the preparation of the substance, a solution of silver nitrate was precipitated with sodium hydrate, and the silver oxide washed by decantation. For each gram of silver nitrate used, there was poured upon the silver oxide 2 cubic centimeters of an ammonia solution containing 25 per cent of NH_3. The oxide of silver dissolved readily leaving only a slight turbidity. The solution thus obtained was divided into several portions, each being placed in a porcelain dish about 10^{cm} in diameter, so proportioned that no dish contained the oxide from more than one gram of nitrate. Each dish was covered with a watch glass and allowed to stand for 16 to 20 hours. The ammonia evaporated and the fulminating silver was deposited, as a black crystalline mass. After washing it was analyzed by digestion with very dilute sulphuric

acid, by which a residue of metallic silver was generally left. The dissolved silver was precipitated with hydrochloric acid, and in the filtrate the ammonia was determined as platino-chloride. The results of sixteen analyses gave ratios which were very close to three atoms of silver for one of nitrogen; leading to the formula NAg_3. Other samples of the substance prepared by warming the ammonia solution of the silver oxide on the water bath, or by precipitating it with alcohol, gave the same ratio on analysis. It exploded by the slightest concussion when dry and requires great caution in handling even when moist. It is soluble in ammonia and in potassium cyanide.—*Liebig's Ann.*, cxxxiii, 93–101, April, 1886. G. F. B.

4. *Formation of Anhydrite or anhydrous Calcium Sulphate.*—The formation of anhydrite has recently been held to require pressure—a pressure of ten atmospheres, which is that of the sea at a depth of about 350 feet. Professor G. Spezia, of Turin, publishes (in the *Atti* of the Turin Academy, vol. xxi, 1886) the following results of experiments by him. The action of aluminum sulphate on powdered apophyllite under a pressure of 300 atmospheres for three months produced *gypsum* instead of anhydrite. The same was the result from a piece of calcite kept in a solution of copper sulphate under 95 atmospheres for three months. He obtained from the reaction of magnesium sulphate with calcium nitrate diffused in water, and in another trial diffused in a saturated solution of sodium chloride, under pressures of 100 and 500 atmospheres, in both cases only gypsum. From these and other similar experiments here mentioned he concludes that some condition besides that of pressure is required to produce anhydrite. The author alludes to methods of obtaining anhydrite, citing G. Rose's results, that gypsum heated to 120°–130° C. in a saturated solution of sodium chloride changed to anhydrite, and that at a lower temperature the reverse took place.

II. GEOLOGY AND MINERALOGY.

1. *Volcanoes of Japan;* by JOHN MILNE (Trans. Seism. Soc., Japan, ix, Part II. Yokohama, 1886. 184 pages, 12mo, with maps and plates).—Mr. Milne gives, in this long and valuable memoir, an account of the many volcanoes of Japan and the adjoining islands, from historical documents and to some extent from personal observations, and illustrates the subject by a map showing their distribution, and by plates containing views of many of the volcanic cones. The highest of them is the noted Fuji-san (=Mount Fuji), by outsiders usually called Fujiyama, near Yokohama. The altitude, deduced from many observations, is between 12,400 and 12,450 feet. It is generally reported to be extinct; but Mr. Milne in an ascent in 1880 saw some steam issuing just outside of the pit of the crater. Of the other volcanic peaks, one (Norikurayama) is 10,447 feet high; Mitake is 10,000 feet; three are between 9,000 and 10,000; two between

8,000 and 9,000 and fifteen between 5,000 and 8,000. Mr. Milne ascended Oshima, an active volcano on the island of that name (height 2,500 feet) in May, 1877, after an eruption which commenced on the 4th of January. The interesting points are that the eruption began with only a very slight vibration or earthquake; the slope on the side ascended was 40° to 50°; explosions within were heard before reaching the top, which were afterward found, when at the top, to occur in succession every two seconds, with occasional pauses, and to be due to successive outbursts of steam, each producing a throw upward of ashes and bombs sometimes nearly to a height of 1,000 feet; the fragments fell vertically or nearly so unless wafted by the winds. The walls of the crater were vertical and about 300 feet in height. The volcano Asamayama, 8,800 feet high (p. 95), is said to break forth in eruption after it has become clogged by depositions of sulphur; but some source of action within must be the real cause of its periods of activity.

The number of volcanoes, easily recognized as such by their cones, is 129, and of this number 51 are still active; 16 of the active are in the Kuriles, 11 in Yezo, and 24 in the central and southern region. Records of 233 eruptions are reported by Mr. Milne (some dating back of the Christian era); 32 of them in the northern district, 63 in the central, and 138 in the southern. Of those whose month of outbreak is known—153 in number—80 occurred in the winter months and 73 in the summer; and the largest number in the months of February and April. The eruptions hence follow, says Mr. Milne, the same law as the earthquakes: "During the winter months the average barometric gradient is steeper than in summer; and this, with the piling of snows in winter, gives rise to long continued stresses, in consequence of which certain lines of weakness in the earth's crust are more prepared to give way during the winter months than they are in summer."

The lavas consist mostly of augite-andesite; but those of Fujisan, Oshima, and Hakone are basic and like basalts, giving for the silica 49 to 52 per cent, with nearly 10 per cent of iron oxides. The rocks are strongly magnetic, and some pieces have been noticed to be polar. Dr. E. Naumann states in a paper in a volume of the Seismological Journal of Japan, that near Ganju-san, for some unexplained reason, the magnetic declination has in the last eighty years decreased 19°, *changing in that time from* 14° 30′ *E. to* 5° *W.;* and that the change is less as you recede from the mountain. Such a fact, says Mr. Milne, makes frequent observations desirable about the large volcanoes that lie in the track of vessels.

Mr. Milne discusses the forms of volcanoes, in continuation of former observations referred to by Mr. Becker in his paper in volume xxx (1885, p. 283) of this Journal. The principle discussed by these authors has reference especially to one of the conditions on which form depends—the resistance to crushing, occasioning "the form due to a self-supporting mass of coherent material." Other causes mentioned by Mr. Milne are the tendency in the larger particles to roll farthest down the mountain; atmospheric denudation; position of crater; direction of ejection; direction of wind during an eruption. These are all conditions pertaining to cones consisting chiefly of fragmental material and have little bearing on the larger volcanic cones or mountains consisting mostly of lavas, among which are those of Hawaii. Outflowing lavas, by cooling around the central vent, with adhesion between the successive outflows, may, as Prévost long since stated (and illustrated by means of beeswax), make slopes of all angles from 1° to 90°. The fusibility of the lavas, the degree of heat above that of fusion, the size of the outflows, the position of the fissures and outflows, all have their effects. Orthoclase lavas, owing to high fusing point, make steep cones or domes, and basaltic lavas those of gentle slope, sometimes as low as 3°. Mount Loa, one of the latter kind, the angle 3° to 8°, has a double curvature in its surface—a flattened or dome-shaped top and wide spreading nearly flat base on its south and southeast sides.* But although almost 14,000 feet high, it is not near the crushing limit of height; for, as Mr. Milne states, even sandstone could be built up, on a base of nine miles in diameter, to a height of 14,500 feet without crushing, and granite to a height of 20,000 feet. The base of Mount Loa is from forty to fifty miles in diameter, and virtually larger, because braced on the north and west by Kea and Hualalai, and the slope about the top is very small. All volcanoes over 5,000 feet in height are probably made at least one-half of solid lavas, although having, it may be, an exterior of fragmental material. The problem of form is therefore a complex one. J. D. D.

2. *Summit crater of Mt. Loa, Mokuaweoweo.*—Mr. ALEXANDER, Surveyor General of the Sandwich Islands, has surveyed the summit crater of Mt. Loa, and we have from him a photograph of his map and an account of the survey. He makes the highest point, on the west margin of the pit, 13,675 feet above the sea-level. As mapped, also by Wilkes, it has a large central pit, with a smaller one on both its northern and southern sides, each of which communicates with the central pit. The length of the whole is 19,500 feet; the greatest breadth 9200 feet; the greatest depth 800 feet; area of central crater 2·3 square miles. It is a marvelous fact that a volcano of so great height should be so frequently in eruption—not usually over its brim, but through fissures commonly 1000 to 3000 feet below it. But, notwithstanding the depth of the pit, outflows from fissures opening to the very summit, and directly on its margin, some-

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* The writer's Manual of Geology, on page 724, has a profile of the island of Hawaii, as seen from the eastward, copied from his Exploring Expedition Geological Report (p. 159), which was drawn by him with much care when *at sea* off the island; it shows, besides the outline of Loa, the contrast between it and that of Mt. Kea. In the view the position of Kilauea was not distinguishable.

times occur, and one such on the southwest side, on the highest part of the brim, is reported by Mr. Alexander as having been a very recent occurrence, and as an immense stream flowing toward Kahuku, besides sending lava cataracts into the south crater. The lava, moreover, is as solid and heavy as that of Kilauea.

With regard to the smaller craters, more than fifty in number, situated about Loa, Kea and Hualalai, the three great mountains of Hawaii, Mr. Alexander states that they have as a general thing been formed on fissures running N. 40°–60° W. though a few are on a N. 50° E. line. "The major axis of the great craters is generally at right angles" to the mean trend of the group N. 30° W.; this is at least true of Kilauea and Mokuaweoweo. "In both of them the highest walls are on the western side, and in both the action is working toward the southwest."

3. *Kilauea, Hawaii.*—The crater Kilauea has again liquid lavas in the pit called Halemaumau, in its southwestern part. On the 26th fires had appeared. On June 29 the lake was about 225 by 435 feet in its diameters, as measured by crossing it, it being crusted over from cooling, but hot for shoes. On July 4th the crusted surface stood at a level 75 feet higher than on the 29th, and two streams of lava 40 feet wide flowed from beneath the table-top of lava into the lower portion of the pit. As usual the lava became cooled in surface to a "satiny blackness" a short distance from its visible source, and this cooling retarded its flow, so that "it 'gartered' itself, as it were, in narrow, smooth folds, arranged in parallel curved lines across the surface of the flow;" but soon the stream, overcoming the partial obstruction thus made, burst through at the front and "rolled out again in slow-moving streams of a rich red color." The display of light in the crater and from the illuminated clouds at night were fine at times during the week. The above facts are cited from letters of June 26th and July 4th in the Pacific Commercial Advertiser, signed C. (F. L. Clarke). The eruption here recorded is one of the common outflows of Halemaumau in the bottom of Kilauea, and not a true eruption of Kilauea.

4. *Map of Maui, of the Hawaian Islands.*—Under Mr. W. D. Alexander, a wall map of the island Maui, 3½ by 4½ feet, has been made, which has recently been published. It is the result of very careful work and gives all topographical as well as political details. It has special interest to the geologist on account of the twin-volcanic character of the island, the contrast in mountain features of the two parts, the wonderful crater of Haleakala at the summit of the eastern part, the highest point of whose rim is 10,032 feet above the sea-level; and the illustrations of the progress of erosion over the two mountain regions.

5. *The Taconic stratigraphy and fossils. Note by* J. D. Dana.—The question has been asked me, in view of the great fault and overthrust in the Scottish Highlands, whether a like event may not have happened in Berkshire, and the juxtaposition of fossils and metamorphic rocks be thus explained. The ques-

tion has been answered, but not directly, in my paper of June, 1885, In view of the enquiry since made I here state the differences. In Scotland, gneissic and other crystalline rocks, through a length from north to south of 90 miles, were carried westward ten miles over scarcely crystalline fossiliferous Silurian rocks, and effects of the friction were visible in the production of metamorphic schists at the contact and in other ways. In Berkshire the facts are as follows:

While the region is one of numerous north and south overthrust folds, with the thrust westward, there is no evidence in the positions of the rocks, abrasions, or in any other way, of a general overthrust.

The rocks within the limits laid down by Emmons are, in most of its cross sections, beginning on the *west* in eastern New York, as follows: (1) Glossy hydromica schist, resembling glossy roofing slate. (2) Feebly crystalline gray to grayish white limestone. (3) Hydromica slates, slightly coarser than (1) and usually somewhat chloritic. (4) Limestone less feebly crystalline than (2). (5) Hydromica schist of the Taconic Range, somewhat coarser than (3) and commonly more chloritic, and less coarse on the western side of the belt than on the eastern, and along the latter sometimes garnetiferous. (6) Coarse crystalline limestones including white to gray marble. (7) Mica schists, often garnetiferous, graduating into and interlaminated at times with quartzyte. (3) Coarsely crystalline limestones, marbles. (9) In some parts, quartzyte which is at times interlaminated with mica schist. (10) Gneiss, mica schist, hornblendic gneiss, etc. In southern Berkshire, as a consequence of the general fact that the metamorphism is greatest to the south, No. (5) is a chloritic hydromica schist, in places somewhat garnetiferous, on the west side, and *mica schist, garnetiferous and staurolitic* on the *east* side, the two sides four to five miles apart.

The nine belts consist alternately of limestone and schist, with quartzyte at the east, 2, 4, 6, 8 being limestones. They vary in width from a fourth of a mile or less to three or four miles or more; and the whole width of the north and south Taconic formation in the section is about twenty-five miles. The dip of all the strata is *in general* eastward and conformable.

If, now, the eastern rocks had been thrust westward over the western, or the western over the eastern, it would be plainly manifest. There is not a shadow of evidence in favor of the idea.

The fossils that have been found within the Taconic system occur in the limestones (2) and (4) just west of the Taconic Range. There is no mica schist within ten miles of them, and the nearest gneiss is 20 miles off. The limestone and the associated hydromica schists are *alike* in grade of metamorphism, both being feebly crystalline.

Four limestone belts are mentioned in the cross section; but in other sections there are only two, and in others five. The

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* This Journal, III, xxix, 441.

schists constitute isolated ridges in what may be called a sea of limestone, and the four limestone belts blend with one another around the ridges; even the most western blending in some places with the eastern. Thus there is oneness in the system of rocks.

The oneness in system and origin is manifested in oneness of gradation in metamorphism, as has been above indicated. The increase in the degree of metamorphic action on going *from west to east* is extremely gradual. It is just such as should follow from variation in intensity of metamorphic action—that is, variation in the degree of heat, moisture and pressure concerned.

Such facts give augmented force to the evidence that there has been no general overthrust. The only rock in the series about which there is any question as to its relative position is that of the quartzyte which occurs here and there over the eastern half and on the eastern margin of the area.

The facts as to oneness of system and metamorphism show also that the fossils have a profound bearing on the whole Taconic system, although found only in the feebly crystalline rocks on the west.

Fossils are not to be looked for in coarse mica schist or gneiss, or in coarsely crystalline limestone. The more or less heated siliceous and alkaline waters at work in metamorphic action tend to dissolve away calcareous fossils. Moreover most shells have thin walls, a large part not over a fiftieth of an inch thick; and hence, if the crystalline grains made by metamorphism are even a thirtieth of an inch across, the shell may disappear. Crinoidal stems and disks are among the most persistent of fossils because of their thickness. The shells of Canaan, as Professor Dwight states, sometimes show that under the metamorphic action they were softened and mashed to pieces, coils unwound and left in bits. The columns of a *Solenopora* are less than $\frac{1}{500}$th of an inch in diameter, and should be obliterated with the slightest change.

Further, hydromica schist, even when fine-grained, is a true mica schist—though containing four or five per cent of water and usually some chlorite—as shown by chemical and microscopic analyses. A hydromica schist is in fact as much a metamorphic rock as a mica schist, although the gradations may be indefinite between it and an argillyte. From Mr. Van Hise's investigations (This Journal, xxxi, 453, 1886), we have learned that mica may be made out of feldspar by metamorphic change, and thus we are relieved of the mysterious fact that mica schists had no mica sediments as predecessors. Hence, from the constitution of mica and orthoclase, *a sediment consisting of detrital orthoclase and clay* (kaolin or decomposed feldspar), half and half or thereabouts, *may*, under heat (with moisture) and pressure, *be converted into a hydromica schist, or else a mica schist, containing about the usual proportion of quartz*, this quartz being the silica set free; and more quartz, if the sediment contained quartz grains. And there is no reason to doubt, in the present state of petrological and metamorphic science, that if detrital augite or hornblende or biotite were present in the sediment, more or less biotite, or chlorite, or garnets, or hornblende might be formed.

Hence with even the metamorphic change producing a hydromica schist, the disappearance of fossils is to be expected, though not always a fact; and that producing a coarse mica schist necessarily exterminates fossils. In conclusion, I believe we may safely regard the Canaan fossils as proof that the limestones and schists of the Taconic system are not older than the Potsdam sandstone. In June last, Professor Dwight discovered another locality of fossils at Canaan, and the locality has afforded *Ophileta* and *Holopea*-like forms, besides others, with numerous small crinoidal disks; and some of the Ophileta-like shells are nearly two inches in diameter. He is at work studying the species and will soon report upon them.

6. *Tertiary Ophiolitic and basic rocks of Scotland and Ireland.*—Signor B. LOTTI (Boll. Com. Geol., April, 1886, p. 73) reviews two recent papers of Prof. J. W. Judd: the Tertiary and older peridotites of Scotland (Q. J. G. Soc., xli, 354, 1885), and the Gabbros, dolerites and basalts of Tertiary age in Scotland and Ireland (ib., xlii, 49, 1866), and presents somewhat similar facts from the Tertiary formations of Italy. Mr. Judd shows that the igneous rocks of the Western Isles of Scotland, of Faroe Island and northern Ireland, which are similar and of Tertiary age, include gabbros (olivine-gabbros of some authors), dolerytes, basalt and basalt-glass; that there is a gradual passage from coarse gabbro, of true *granitic* type of texture, to tachylyte or basalt-glass; that porphyritic kinds occur in the several terms of the series down to that of basalt-glass; that unaltered and altered kinds of several of the rocks occur, and that neither differs from similar rocks of pre-Tertiary age; that the altered forms include saussurite-gabbro (having the feldspar changed to saussurite and the augite more or less to foliated hornblende); that the gabbro passes into picryte by the disappearance of the feldspar, into trocholyte by the disappearance of the augite, and into eucryte by the disappearance of olivine; that the gabbros, dolerytes, basalts and tachylytes do not present any essential difference in their bulk-analyses; that, in the incipient stage of change, augite often assumes the foliated structure of diallage and lustre of bronzite or schiller spar, a process which Mr. Judd names *schillerization*, and that it may pass thence, by further change, into serpentine, though the alteration of olivine is the common source of the serpentine.

Signor Lotti cites also the paper of Hague and Iddings with regard to the gradation between granitoid and basaltic forms of the same igneous mass in Nevada. He describes the ophiolitic Tertiary rocks of Italy as intersecting and interlaminated with Eocene strata; as including euphotide (gabbro), diabase (dolerkyte), and serpentine; the euphotide as labradoritic, or saussuritic (most common), or olivinic, or serpentinous (very common), and as associated with hypersthenyte, lherzolyte, and granite; the diabase as aphanitic, or microcrystalline, porphyritic, amygdaloidal, or chrysolitic, and by alteration becoming gabbro rosso, and variolitic and uralitized diabase. He observes that these rocks occur in close association, the diabase forming the upper portion of an ophiolitic mass, and the euphotide in intercalated beds or masses; and that the serpentinous change has often penetrated into the enclosed argillaceous sedimentary beds of the Eocene; that the idea of a pre-Eocene age, assumed by some, is wholly opposed by the facts. In the amount of alteration, the region differs from the Scotch and Irish described by Mr. Judd; and the eruptions in Italy were submarine instead of subaerial.

From numerous observations it is shown that the euphotide and diabase are parts of the same eruptive magma, and that the former is simply a result of slower cooling, becoming true granitoid in texture in the deeper portions of the originally liquid mass.

Signor Lotti says that in Italy the term gabbro cannot be used for a labradoritic euphotide, as now common in lithology, because it retains there its original use for a serpentine rock, *gabbro verde* being the unaltered and *gabbro rosso* the altered and reddened. This fact is enough to condemn the term to banishment from science. J. D. D.

7. *Onus probandi left for others.*—The leaving of the *onus probandi* for others is no uncommon occurrence in science. But it has recently been dignified by being presented as a worthy geological method by a distinguished English geologist on a prominent occasion. He opens his discussion, and confidently ends it, with the sentiment that "while admitting the possibility of these identifications [those of schists and gneisses with any of the strata of Palæozoic or later age] the evidence in their favor has been in so many instances proved to be fallacious that the *onus probandi* lies on him who asserts, not on him who denies the identification." This means that, in cases of doubt, one side may be assumed to be true by the self-convinced geologist until the other has been proved true by somebody else. It is a method of dealing in science that is likely to turn out disastrous, not to truth, for others will investigate, but to the positivist who finds comfort in *his* truth however much he may think himself sustained by "all the rules of evidence and reasoning." The same memoir says, in another place: "all attempts to identify large groups of metamorphic rocks with strata of post-Archæan age have proved to be failures." So Professor Bonney thinks. The really progressive geologist—not of "the new school in geology" of and for which he speaks—would reverse this statement and say: The identification of all large groups of metamorphic rocks with strata of Archæan age has not yet been accomplished. This is the precise fact.

Again he says: "It will surprise me if the comparatively late date assigned by some geologists to the marble of Carrara proves to be correct"—a statement which, in justice to Italian and other investigators, and to right scientific methods, had better have been withheld, and kept in the form of a private doubt, until the author of it had investigated the region; for it is putting his ignorance against others' knowledge in a case where only field-study can decide as to the truth.

The difficult question with regard to the age of metamorphic rocks over the globe has had, in fact, little careful study, and partly because of "settled opinions." Work however is going forward by geologists who are not disposed to avoid the *onus probandi*, and a chronological scheme probably will be finally arrived at based on positive knowledge of the kinds that were made in successive ages. J. D. D.

8. *Preliminary Report upon Petroleum and inflammable Gas of Ohio*, by E. ORTON, State Geologist. 76 pp., 8vo. Columbus, O.—Mr. Orton treats of the geology of the petroleum and gas of Ohio, and also of matters of economical interest. The rock yielding the large supplies of these materials in Ohio is the Trenton limestone, in Wood, Hancock and Allen Counties of northwestern Ohio. Borings go down a thousand feet or more below the surface, but not over 50 feet into the Trenton. At Findlay, in this part of Ohio, the Karg well yields 12,000,000 cubic feet of gas a day. Oil and gas are also obtained from the Berea grit, a sandstone of the Subcarboniferous, in eastern Ohio. But its largest gas-well yields only 35,000 cubic feet per day. In some places the overlying sandstones of the Waverly and Coal measures are sparingly productive. Some oil and gas come also from wells in the Devonian shales, but the supply is small. In a very moderate way gas is derived from borings into the glacial drift, and the supply is sometimes sufficient for "household service" and "has been so used for many years at a number of points in Champaign Co., Illinois." At St. Paris, Champaign Co., Ohio, a place 1237 feet above the sea-level, the drill went down 510 feet through drift before reaching solid rock; and at 400 feet passed much vegetable matter, as tree trunks (red cedar) and branches and black soil. Such vegetable deposits have been found at many places in the drift of Ohio, and are the source of the gas the drift occasionally affords.

The Findlay gas was found by Professor C. C. Howard, of Columbus, to contain marsh gas, or light carburetted hydrogen 92·61 p. c., olefiant gas 0·30, hydrogen 2·18, nitrogen 3·61, oxygen 0·34, carbonic acid 0·50, carbonic oxide 0·26, hydrogen sulphide 0·20=100.

9. *A peculiar feature of the Clay-beds on the west bank of the Hudson, 3 miles north of Newburgh.*—These beds are described by Professor Wm. B. Dwight (Trans. Vassar Br. Inst., Poughkeepsie, 1884, '85) as inverted conoidal masses of clay made by the filling of large conoidal depressions in sand-beds. Three conoidal masses of clay have been opened. One of the inverted conoids is elliptical in cross section, 80 by 50 feet at bottom and

150 feet in longest diameter at top; and the depth is 90 to 100 feet. The other two are of like size in the same line parallel with the Hudson, and only a few yards apart. The clay is in regular concentric layers, being deeply concave downward, and is of excellent quality. The sand and gravel beds outside are bent downward at the wall of the cavity; and the wall, or shell, was quite distinct and rather firm. There are a few bowlders in the clay. Professor Dwight supposes that the sand and gravel beds (stratified drift of the Hudson river valley) were excavated by whirlpools, and the conoidal basins thus made; and that these cavities, when the chief current of the stream had become diverted from the place, became gradually filled with clay. Still another peculiar feature is described and figured in this paper, which is not so easily explained.

10. *On the Fossil Flora of the Laramie Series of Western Canada;* by Sir William Dawson, LL.D., F.R.S.—The Laramie series, formerly known as the Lignite Tertiary or Lignitic group, occurs in Canada principally in two large areas west of the 100th meridian and east of the Rocky Mountains, and stretching northward from the United States boundary. These areas are separated from each other by a low anticlinal of Cretaceous beds, over which the Laramie may have extended previously to the later denudation of the region.

These areas may be designated—(1) The Eastern or Souris River and Wood Mountain area; (2) the Western area, extending along the eastern side of the Rocky Mountains, and across the upper waters of the Bow, Red Deer, Battle and North Saskatchewan Rivers.

In the southern part of the District of Alberta it has been found possible to divide the Laramie into three parts, which have been named respectively, in the Reports of the Geological Survey of Canada, (1) the lower or St. Mary River division, (2) the middle or Willow Creek division, and (3) the upper or Porcupine Hill division. Of these the lower and upper contain fossil plants, more especially the latter, and corresponding horizons can be recognized by these in both of the great areas above referred to. The flora of the lower division has a close alliance with that of the Belly River group of the underlying Cretaceous, while that of the upper division is in the main identical with that of the Fort Union group of the United States geologists, as described by Newberry and Lesquereux.

In the eastern area, the lower beds of the Laramie rest on the Fox Hill group of the Cretaceous, and are in turn unconformably overlaid in the Cypress Hills by beds referred by Professor Cope, on the evidence of mammalian remains, to the White River division of the Miocene Tertiary. Thus the geological horizon of the Laramie is fixed by stratigraphical relations as between the upper Cretaceous and lower Miocene formations. The evidence of fossil remains accords with this position. The lower Laramie has afforded reptilian remains of Mesozoic aspect, associated with fishes and molluscs, some of which are of Eocene types, according to Cope and Whiteaves, and its flora is akin to that of the upper Cretaceous. The upper Laramie has offered a flora so modern in aspect that it has even been regarded as Miocene, though in reality not later in age than the Eocene. The Willow Creek or middle Laramie division may therefore (as suggested by the author in his memoir of last year on the western Cretaceous) be regarded as the transition from the Cretaceous to the Eocene.

The question of the correlation of the Laramie with other formations has been much complicated by the reference, in the United States and elsewhere, of beds holding its flora to the Miocene period, and these difficulties cannot as yet be wholly overcome, though they are gradully being removed. In Canada, since the plants began to be collected and studied there has been little doubt on the subject, and the author now, as heretofore, holds to the correlation with the Laramie flora of the so-called Miocene of Mackenzie River, Alaska, Greenland and Spitzbergen, and believes that they should be regarded as not newer than Eocene.

The greater part of the paper is occupied with the description of the fossil plants of the formation, including those collected in the Eastern area by Dr. Selwyn and Dr. G. M. Dawson, and those obtained from the Western area by the latter, Mr. Weston, Mr. Tyrrell and the author. These include a large number of exogenous trees, all belonging to modern genera, as *Platanus*, *Corylus*, *Populus*, *Salix*, *Viburnum*, *Carya*, *Juglans*, etc. There are also some curious plants allied to the modern trapa or water chestnut, and coniferous trees of the genera *Taxodium*, *Sequoia* and *Salisburia*, as well as some ferns and equisetaceous plants of much interest, more especially in reference to their geological and geographical distribution.—*Abstract of Paper read to Royal Society of Canada*, May, 1886.

11. *On the Decay of Building Stones;* by T. EGLESTON (Am. Soc. Civ. Eng., xv, 1886).—In this paper the writer reviews some of the causes of decay affecting building stones, especially such as depend on the removal of an ingredient by solution or decomposition. Many facts of interest are reported. Among the observations he mentions that dolomitic limestones, which in many regions crumble to sand, in the case of monuments as well as in those of the native ledges, owe this to the fact that they are to a large extent mixtures of true dolomite and limestone; and that the limestone, the most soluble portion, is dissolved and removed by percolating carbonated waters.

12. *Geological Studies, or Elements of Geology for High Schools, Colleges, Normal and other Schools;* by ALEXANDER WINCHELL, LL.D. 514 pp. 12mo, with 367 illustrations. Chicago, 1886. (S. C. Griggs & Co.)—In this work Professor Winchell shows the hand alike of an instructor, a thinker, and a field-observer. He introduces the student to the subject by presenting first a chapter on the drift and some other phenomena over the earth's surface open to ordinary observation, sometimes considered

under the head of Surface Geology. The subject of minerals and rocks is next treated with some detail, and then that of sedimentary erosion, stratification, geological maps, volcanoes, mountains and mountain formation, veins and ores, and the characters of some common fossils. After thus giving the learner some of the general facts of the science, Part II follows, with the title, Systematic Studies. Under it, the chapters treat in succession of lithological, structural, dynamical, paleontological, formational and historical geology. The illustrations of the volume are excellent.

13. *Glacial action in Australia.*—Mr. J. Stirling reported before the Linnæan Society of N. S. Wales, in May, that during a recent visit to Mount Bogong, the highest mountain in Victoria (South Australia) he found erratics, perched blocks, smoothed surfaces and old moraines, affording fresh evidence in favor of glacial action.

14. *Analysis of Biotite* by Edo Claassen (communicated).—The biotite, which is found intimately associated with the magnetite of the Lake Superior Iron Region, occurs compact massive or as an aggregate of small scales. It is dark olive-green or greenish black in color, and has a specific gravity of 2·7. It is easily decomposed by hot hydrochloric or sulphuric acid, leaving the silica in scales. An analysis yielded :

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	K_2O	TiO_2	H_2O	Cl	undecomposed
32·02	20·38	7·15	18·36	0·45	7·84	5·91	2·38	2·71	0·02	0·99=98·21

III. BOTANY.

1. *Lloyd's Drugs and Medicines of North America.*—This great repertory of the materia medica and pharmacy of the flora of North America has now promptly entered upon its second volume, in its June number, devoted to *Liriodendron* and some of the species of *Magnolia.* Eighteen pages and one fine plate are given to the tulip-tree. A. G.

2. *Cypripedium arietinum* in the mountains of China is a notable addition to an already very considerable list of disjoined species, divided between Eastern North America and Eastern Asia, with prolongation in the Himalayas. It is M. Franchet who announces this instance in *Bull. Soc. Bot. de France,* vol. xxxiii, p. 206. Almost as unexpected as the instance itself is M. Franchet's accompanying announcement of it as a wholly unparalleled case of such distribution. Not to mention the recently accrued instance of *Liriodendron,* there is the very old one of *Phryma,* and a good many more of the same character. A. G.

3. *Index to the Botanical Gazette.*—Along with the July number of this periodical we receive the index to volumes i to x (1875–1885), filling 29 pages. It is a triple index, viz: of subjects, of authors of articles, and of illustrations. It is not issued as a part of the July number, which is a full one of 36 pages, and is therefore a free gift of the editors and publishers, Professors Coulter, Arthur and Barnes. The improvement of this useful

journal in typographical appearance and dress, as well as in matter and handling, is as great as its increase in size in this its eleventh year. It is wonderful that it can give so much for the subscription price of two dollars a year. A. G.

4. *The Cayuga Flora:* Part I. *A Catalogue of the Phænogamia growing without cultivation in the Cayuga Lake Basin;* by WILLIAM K. DUDLEY. Ithaca, 1886. 8vo., pp. 132 and an index.—This is the first part of vol. xi of the Bulletin of Cornell University, which is now revived in affectionate and revered memory of the late Professor Hartt, who originated it in the year 1874. It promises to be a worthy continuation of a series nobly begun, and Professor Dudley has evidently done his work conscientiously and well. The plan, the typography, and the treatment are to be commended. The introductory account of the Cayuga flora, its topography (illustrated by two maps), statistics and the history of exploration of the district are quite interesting and would tempt us to some detailed notice, if time and space permitted.

The reference to John Bartram as the first botanical explorer of the region recalls a fact, recorded in this Journal a few years ago, which might have been noticed under *Selinum Canadense.* For this is the "*Athamantha Chinensis*" of Linnæus; and the solution of his riddle, "Habitat · · · *Chinensem dixit Barthram*, qui semina misit ex Virginia," is this. Bartram picked the seed probably in the neighborhood of Ithaca and sent it to Linnæus as from the "Genessee country" (the general name of that part of New York in those days), and Linnæus, or the Upsala gardener, somehow mistook Bartram's *Genesee* for *Chinesé.* A. G.

5. *Catalogue of the Plants in the Herbarium of the College of Science, Imperial University, Tokyo, Japan.* P. Maruya & Co. 2546 (1886).—A handsome volume of 287 pages, in small octavo, with a few pages of corrections, with an explanatory preface in Japanese, the botanical names of the species and authorities in Roman type, the popular names and other matter in the Japanese character. The name of the compiler (evidently no mean botanist) is not given. We receive the interesting volume "with the compliments of H. Watanabe, President of the University," to whom we would offer thanks and congratulations. It is interesting to receive upon the same day these contributions to botany from the Cornell and from the Tokyo Universities. A. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Races of Britain*, a Contribution to the Anthropology of western Europe; by JOHN BEDDOC. Bristol, England. 272 pp. 8vo, 1885. (Trubner & Co., London.)—The title of this work hardly gives an idea of its scope. It is a learned discussion of the facts connected with western Europe as well as British races, prehistoric and historic, Roman, Saxon, Frisian, Germanic, Danish, Norman, etc., on the origin of the race peculiarities in Britain.

2. *Estudios de Meteorologia Comparada*, por MARIANO BARÇENA *y* MIGUEL PÉREZ. Vol. I, 438 pp. 8vo. Mexico, 1885.—This government publication on Mexican meteorology contains the results of the observations made by the Central and other Meteorologico-magnetic Observatories of Mexico. It is the first of a series of volumes, and covers the months of January to April, 1881.

3. *Monument to Horace-Benedict de Saussure.*—H. B. de Saussure, the eminent meteorologist, geologist, and explorer of the Alps, died in the closing year of last century. A circular letter signed by Professor A. Favre of Geneva states that it is proposed to erect a monument to his memory to "be placed at the foot of Mont Blanc, whose lofty summit the illustrious savant reached," not far from the Col du Géant,—where amidst snow and ice he was encamped for sixteen days. The inauguration is planned for the 3d of August of 1887, the centenary of his ascent of Mont Blanc. The character of the monument will depend on the amount that may be received from the admirers of the intrepid explorer.

4. *Biographies of American Naturalists*, III. *Publications relating to Fossil Invertebrates*, by J. BELKNAP MARCOU, Bull. U. S. Nat. Mus., No. 30. 334 pp., 8vo. Washington, 1885.—This number of the very valuable series prepared by Mr. Marcou contains lists of the publications on fossil invertebrates, and of all species described in the publications, by the following authors: F. B. Meek, C. A. White, C. D. Walcott, J. W. Bailey, J. D. Dana, C. G. Ehrenberg, James Hall, A. Heilprin, A. Hyatt, J. Marcou, J. S. Newberry, D. D. Owen, J. Schiel, B. F. Shumard, R. P. Whitfield, T. N. Nicollet and H. A. Prout.

5. *La Terre des Merveilles; Promenade au Parc National de L'Amerique du Nord;* par JULES LECLERCQ. 384 pp. 16mo, with several plates of the geysers. Paris, 1886 (Hachette & Co.).—A popular work in French on the Yellowstone Park, the facts and figures derived from the reports of Hayden's Expedition.

OBITUARY.

1. Dr. HERMANN ABICH, the distinguished Austrian geologist and mineralogist, died at Vienna on the first of July. He was born in Berlin on the 11th of December, 1806. He commenced his publications in 1831, with a paper on the composition of the species of the spinel family. His explorations of Etna and Vesuvius were followed by various papers and by the publication in both French and German of a folio atlas entitled "Vues illustratives de quelques phénomènes géologiques, prises sur le Vésuve et sur L'Etna," published in 1837 and his "Geologische Beobachtungen über die vulkanischen Erscheinungen" of 1841. He was long professor of Mineralogy at Dorpat and made explorations in the Caucasus and Northern Persia, and a large work entitled "Geologische Forschungen in den Kaukasischen Ländern" was in course of publication at the time of his death, only the first part having appeared. He was an able worker in science of great energy, and continued so to the closing year of his life.

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SCIENTIFIC INTELLIGENCE.

Charles D. Walcott,
Office Geological Survey.

No. 190. Vol. XXXII. OCTOBER, 1886.

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THIRD SERIES.

VOL. XXXII.—[WHOLE NUMBER, CXXXII.]

No. 190—OCTOBER, 1886.

WITH PLATES V TO IX.

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXVIII.—*A dissected volcanic Mountain; some of its revelations;* by JAMES D. DANA.

THE island of Tahiti—the largest of the Society Islands—affords excellent illustrations of two widely different subjects:

I. Erosion by running waters; and

II. The inner structure of a great volcanic mountain.

I have described the features of the island in my Geological Report of the Wilkes Exploring Expedition,* from observations made in 1839, and have pointed out the bearings of the facts on the two subjects, but I give there no map of the topography, or views of the peaks; and I now return to the subject to add these illustrations with some further remarks.

The island has nearly the shape, as regards outline, of a letter 8, and was once a twin of volcanoes. Only the northern and larger of the two peninsulas is often visited, and of that I speak. It was originally a gently sloping cone of the type represented by the Hawaian volcanoes; for its beds of lavas, as seen in the sides of the valleys, slope at a small angle toward the shores; mostly 3° to 10°—varying in some parts to 15°—on the north and west sides, where my examinations were made. Supposing the mean slope to be 8° the height above the sea-level of the original cone—the diameter of the island being twenty miles—would have been nearly 7500 feet. But

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* Pages 283 and 386 of the quarto volume (of 756 pp. with a folio Atlas) published in 1849. See also Abstract of part of the results, this Journ., II, ix, 50, 1850.

the slopes above may have been steeper and the height much greater. The greatest height at the present time according to an imperfect measurement made by Lieut. W. M. Walker, U. S. N. (who took as a base a line measured on the coral reef near Matavai) is about 7000 feet.

The old cone is now a dissected mountain. Valleys cut profoundly into its sides, and lay bare the center to a depth of from 2000 to nearly 4000 feet (by estimate) below the existing summit; and the deep valleys so crowd on one another that the dissection is complete.

The topographic features of the island are shown on the accompanying map. This map is a copy in the main of that in Captain Wilkes's Narrative of the expedition. "In the main," I say, because I have made changes, removing some of the imperfections introduced by the art of the map-maker or engraver and his want of knowledge of the region. I should not have taken this liberty were it not that part of the map was originally from a sketch of my own, communicated to the Hydrographic department of the Expedition. My sketch comprised the northern third of the island, from the center outward, between the Papenoö and Punaavia valleys,* and was prepared from personal observations in the valleys of the region, and on an ascent of Mt. Aorai, one of the two highest peaks. Being the only person of the Expedition that made the ascent, no other one had the opportunity for so comprehensive a view of the ridges and valleys of that part of the island.* Of the central peaks, the highest, at *a* on the map, made 7000 feet in height by Lieut. Walker's measurement, is called *Orohena*; the next highest, about 500 feet lower, at *b*, is the one called Aorai.†

I. *Erosion.*

As the map shows, the island in its present condition is an admirable model of a deeply denuded or water-sculptured mountain cone. To appreciate the precise conditions under which the denudation went forward it has to be borne in mind that the waters from the rains and clouds are most abundant about the summits and higher portion of the island, and are there perpetually at work. In these upper parts, therefore, or above 1500 feet, forests and shrubbery cover the ridges and valleys wherever there is a foothold; but toward the coast, or

---

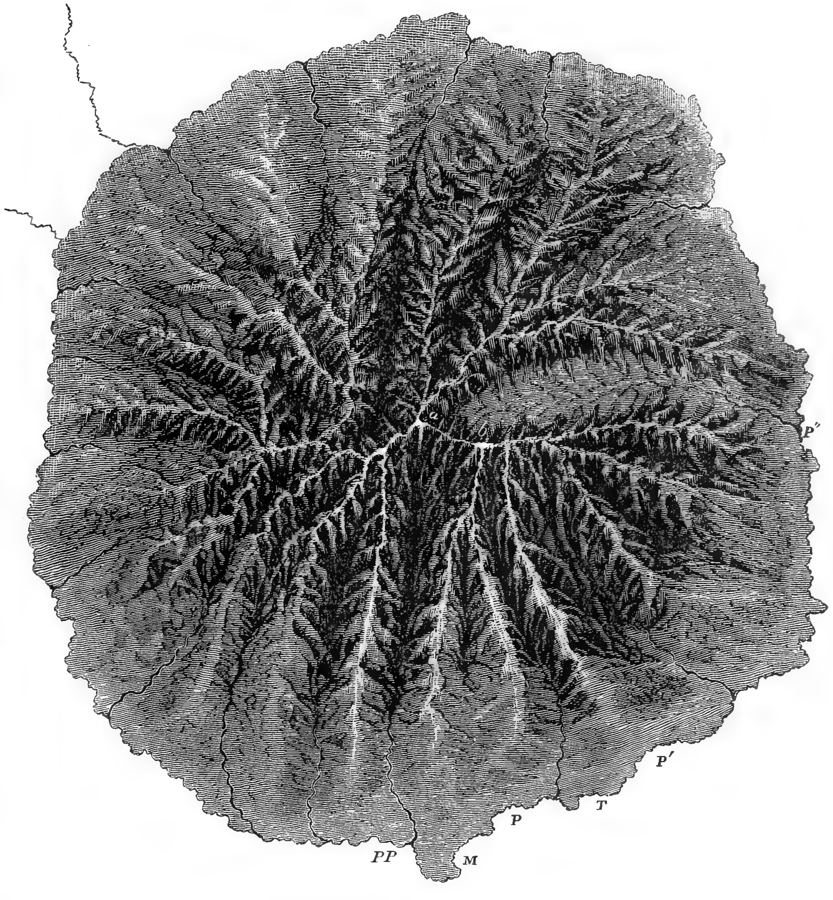
* On the ascent and at the summit I took some bearings, but I made no attempt at a trigonometrical survey, and the map is still unsatisfactory in its minor details; but it well illustrates the points in view.

On the excursion I had with me only two Tahitians. The ascent was made after Captain Wilkes had left Tahiti with his vessel, the Vincennes, and hence the mistaken statement in his Narrative that I was accompanied by others of the expedition.

† These words are pronounced O-rò-he-nàh and Ow-ry.

below a level of 1000 to 1500 feet, the slopes, down to the grove-clad border-plain of the island, are grass-covered and look bare in the distant view.

1.



Map of Tahiti, the coral reefs excluded; the lower side is the northern, or that toward the equator: PP, village of Papenoö; M, of Matavai; P, of Papaua; T, of Toanoa; P′, of Papieti, the largest; P″, of Punaavia. The valleys are named from the villages on the coast at their termination.

The following are the features due to the erosion:

(1.) The ridges and valleys are arranged nearly radially.

(2.) The highest peaks are about the center.

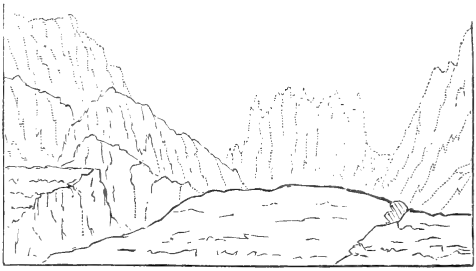
(3.) The valleys terminate for the most part near the sea-level instead of extending deeply beneath it, as shown by the fact that the outline of the island is nearly even, instead of being indented with deep bays.

(4.) The larger of these valleys abut at their heads against the central peaks in lofty precipices—precipices of two to nearly four thousand feet. Some of the larger valleys are widest at the center of the island and terminated under the peaks in vast amphitheatres.

(5.) The ridges toward the borders of the island are somewhat broad-backed, but, over the interior, very narrow. Above an elevation of 3000 feet or so (as I found in my ascent), the top edge of the ridges for much of the way is but three or four feet wide—too thin to be represented on a map of so small scale as the above; and in some spots it diminishes to a foot, and even, at times, to a thin edge of bare rock; and from the crest the declivities either side pitch off steeply 1000 to 2000 feet.*

(6.) Within a mile or two of the central peaks erosion has reduced the height of some of the narrow ridges a thousand feet or more, or still further lowered and thinned them until dwindled to a mere pinnacled wall at the base of the peaks.

2.



The "Crown" at the head of the Papiete Valley.

A view of a portion of one of these thinned-down ridges, called, on the island, the Crown, I here introduce from my note-book.† The ascent of one of the highest peaks is possible only along a ridge that has kept unbroken its connection with the summit, and an experienced guide is needed to make sure of the right and safe way.

My own ascent of Aorai was made by the ridge that forms the west side of Matavai Valley (the valley which terminates

---

* The chief error in the map as published in the Narrative arises from the covering of the ridges with the conventional hachures for vegetation—these giving them a width of a fourth to half a mile instead of a yard or two. The top edge is covered with shrubbery, and it serves the mountaineer a good turn by shutting from view the steep slopes alongside.

† The "Crown" is at the head of the Papiete Valley, between it and the Punaavia Valley.

at M on the map); and my return was by the west side of the Papaua Valley, that next west of the Matavai Valley. The top of Aorai was found to be "not six feet broad; beyond it, the mountain ridge continued for a short distance, with the same sharp, knife-edged character, and then was broken off by the Punaavia valley," while "at its western foot appeared 'The Crown.'" Across a valley, 3000 to 4000 feet deep, stood Orohena, only two miles distant, with nearly erect sides and equally sharp crest; and similar features characterized the other ridges in the panorama.

I refer the reader to my Expedition report for the details, and for a discussion on valley-making about volcanic mountains and elsewhere, including the formation of the amphitheatres and a detailed description of the steps in the progressing erosion changing the finished volcanic cone into a Tahiti, illustrated by facts from Hawaii and elsewhere. "Mount Loa, alone, contains within itself the material from which an island like Tahiti might be modeled that should have nearly twice its height and four times the geographical extent." (Rep., p. 392).*

II. *The inner Structure of a great Volcanic Mountain.*

The above facts with regard to the dissected island have their chief interest as an introduction to the second subject of my paper—*The inner structure of a great volcanic mountain.* The profound dissection has laid open the island to its very core, and to a depth below the *original* summit of certainly more than 4000 feet. If, as we may suppose probable, the old cone had, like Mt. Loa or the Maui volcano, a great pit-crater at top, the interior must be open to view for at least 3000 feet below the bottom of the crater.

Although my time at the island did not allow of a thorough exploration of the central region, one point of fundamental significance was made out, and put beyond question: that the mass of Orohena was not composed of beds of lava. There were no horizontal (or nearly horizontal) lines or divisions. Instead, there were vertical lines indicating vertical joints or an imperfect columnar structure, in the unstratified mass; and this was true for the mass to the very top.

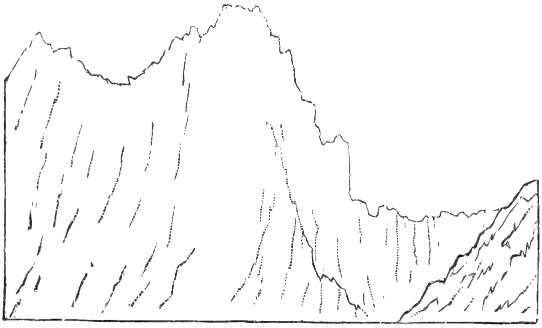
---

* Descriptions of the results of erosion are given in my Report, in connection with the special accounts of several of the islands visited, and of Australia, and in chapters on the origin of valleys, on pages 379 to 392 and 526 to 533. A brief statement of the general results is made in my Manual of Geology, p. 642.

A similar history of the process with similar descriptions of "knife-edged ridges," amphitheatres, etc., is contained in Capt. Dutton's Report on the Hawaian volcanoes, published two years since by the U. S. Geological Survey. As he makes no mention of my volume, or even of its title or its author, in his work, I may add that his readers can at least supplement their knowledge on the subjects treated by consulting my report of thirty-seven years since.

This remarkable feature has been little appreciated notwithstanding my report on the facts. I was recently gratified to find that I could fortify my descriptions by means of outline sketches of Orohena from my note-book of 1839, which have till now remained unpublished. The views were taken from points toward the top of Aorai when on my ascent. They are closely alike, but differ enough (because taken from points of different elevation) to corroborate one another. They show no horizontal lines and place the fact of their absence beyond question. In that region of luxurious tropical growth, had there been distinct bedding in the face of Orohena, unequal erosion would have made recesses and projecting shelves, and occasioned corresponding lines of shrubbery; and even if the faintest horizontal divisional planes existed, the oozing out of waters would have produced bands of green from the growth of mosses and other vegetation. But there were no shelves, or bands. The surface in view was nearly bare of vegetation.

3.



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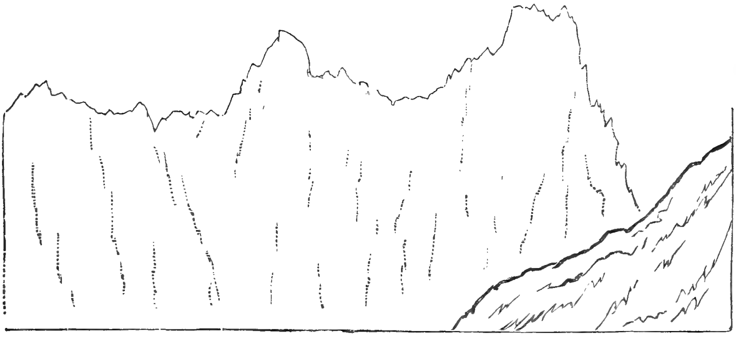

Sketches of Orohena as seen on the ascent of Aorai. Orohena, the highest summit; the other peak, to the left, Pitohiti.

Such features are in striking contrast with those observed in the lower or outer part of the mountain. Toward the coast stratified lavas are seen along the valleys, and the layers are usually but twenty feet thick or less. The vesicular lavas, the larger part a chrysolitic basalt, alternate with layers of tufas and conglomerate. But five or six miles up one of the valleys (the Papenoö), the layers of lava were much thicker, and, as my Report states, some bluffs a thousand feet in height constitute apparently a single bed, and are more or less columnar throughout. This greater thickness of the beds on approaching the center appears to show that the eruptions were far more copious early in the history of the volcano than they were later. But this is not an explanation of the massive structure of Orohena. The uniform massiveness through so great height at the volcano's center has plainly come, as I long since stated, from the cooling of continuously liquid lava at the center, or in the region of the great central conduit of the cone.

We appear to have an explanation of the facts, or a suggestion toward an explanation, in the condition of Mount Loa, on Hawaii. At the beginning of one of its great eruptions the central mass of liquid lavas stands at a height of more than 12,000 feet above the sea-level; and the breadth of the liquid mass at top, if of the size of the crater (as it sometimes has been), is over 8,000 feet. To appreciate the conditions it is to be considered that the summit-crater of this great volcano has been in eruption on a grand scale *eight* times since 1843,—the last time in 1880–81; or, on an average, once in five years; and that the fires at some of these times of activity have continued active, at heights of 10,000 to 12,000 feet, for 10 to 18 months. A mass of liquid rock at the mountain's center 10,000 to 12,000 feet high above the sea-level and at least 5,000 feet in breadth near the top is not an exceptional condition in the volcano; it may be often true.* If 5,000 feet broad at top, the breadth would be greater below as it descended toward the deep region of continuous or wide-spread liquidity. Suppose such a mountain to have its last eruption and then to cool off, and become extinct. The central liquid mass, in such a case might perhaps retreat downward as a consequence of escape, either outside or subterranean, and a great cavity be left. But if pressure from below and resistance to fracture should hold the lavas to their place, as it did in the case of the ejections making the laccoliths of the Gilbert Mountains described by Professor Gilbert, they would cool there, and the liquid central mass would become the solid central mass.

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* On the size of the crater (called Mokuaweoweo) and the height of the mountain, see page 235 of this volume; and on the area of sinking, and therefore of liquid lavas, in Kilauea at one of its eruptions, see the last volume, p. 398.

It can hence hardly be doubted that a massive central structure, like that revealed in the dissection of Tahiti, is a common feature of the *greater* volcanic mountains that have become extinct.

The slow cooling, extremely slow, on account of the magnitude of the mass, and under great pressure moreover, would have caused the lava to solidify into a *compact* crystalline rock, and often into a *coarsely crystalline* rock.

I found evidence of the massive condition and slow cooling of the rocks of the interior of the island in one of the valleys leading to the center. Up the Papenoö Valley six to eight miles from the coast, along the stream, I found many worn masses of a whitish granite-like dioryte.* It had evidently been brought down the valley from one of the central peaks at its head, either Orohena or an associate; and the conclusion seemed to be unavoidable that the difference between it and the lavas below in compactness and grade of crystallization was due to difference in pressure and rate of cooling; and I say (Report, p. 377) that although the liquid rock of volcanic outflows generally cools without distinctly visible crystallization, or with only crystals of feldspar, or of augite, in a compact base, "the cooling is sometimes sufficiently gradual to allow of the whole crystallizing; and in this case, the texture throughout is crystalline and the rock much resembles a granite," and I add further: "Under the same circumstances (or even a less gradual cooling) the elements of augite present will crystallize as hornblende, for these two minerals are identical except in crystallization, and this difference depends on temperature and rate of cooling, hornblende requiring the slower rate." In this way I explain the formation of the dioryte, a hornblende rock. I thence remark (p 378): "Thus we arrive at the same statement with which we commenced, that particular rocks have no necessary relation to time on our globe, except so far as time is connected with a difference in the earth's temperature or climate, and also in oceanic or atmospheric pressure; for if the elements are at hand, it requires only different circumstances as regards pressure, heat, and slowness of cooling, to form any igneous rock the world contains."†

This conclusion had not a full basis of facts; for I had not collected specimens from the bases of those central peaks. But it was right, as I have believed ever since the visit to Tahiti and

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* The rock is called syenyte in my Report; but I describe the feldspar as near albite, recognizing thus its triclinic character. I give the specific gravity as 2·73. My excursion up the valley was cut short by a circumstance beyond my control and hence the specimens were not traced to their source. The specimens I left in 1844 in Washington, where they were deposited under Government orders.

† The same chapter in my Report (p. 375) contains a suggestion as to the increase in the feldspathic character of the lavas in the central conduit of a volcano through a prolonged liquation-process, which has not been sustained by facts.

Hawaii in 1839 and 1840. The idea is now no longer a half-studied conclusion, but, thanks to the elaborate investigations of Messrs. Hague and Iddings, and of Allport, Judd and others, it is an *established* fact in the science of igneous rocks.*

ART. XXIX.—*Origin of the Ferruginous Schists and Iron Ores of the Lake Superior region;* by R. D. IRVING.

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TWO classes of theories have been maintained to account for the iron ores of the Lake Superior region. According to one of these, these ores, with more or less accompanying rock material, and particularly the jaspery schists so often associated with them, are in the main of eruptive origin; according to the other they are of sedimentary origin, the original sedimentation having been mechanical, or chemical, or both, according to different theories. On the eruption theories subsequent chemical alteration is allowed to come in to some extent to explain present conditions, as it is also with some of the sedimentation theories; but the latter theories appear to appeal in the main to a regional metamorphism as the cause of present conditions.

Those who have maintained the theories of a sedimentary origin have relied chiefly upon the common intimate interlamination of siliceous and ferruginous materials; upon the manifest restriction of the ores and jaspery schists to definite stratigraphical horizons; upon their interfolding with other members of the same series, and upon their apparent gradation in places into plainly fragmental deposits. These conditions being taken to indicate original sedimentation, different authors have imagined the unaltered deposits to have been argillaceous carbonates like those of the coal measures; to have been brown ores like those found under bogs, or accumulating in shallow lakes, at the present day; or to have been magnetic iron sands like those of modern sea shores. All of these theories appear to regard the silica of the jaspery schists and ores as having been sand; its present non-arenaceous, non-fragmental condition being taken to be the result of metamorphism.

Advocates of an igneous origin for the iron ores and associated jaspers have been few; and it is noteworthy that their

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* My twenty-five days at Tahiti, in the early autumn of 1839, were divided up between the study of the coral reefs, the collection and study of the Crustaceans of the coast (both of which were part of my assigned duty), and geological explorations over the island; and our day of departure came almost immediately after my ascent of Mt. Aorai, in which I had become aware of the deep interest of the problems the island illustrates. My visit to the Hawaian Islands came a year later.

observations have been confined to the Marquette region, where the disturbances have been great, and where the difficulties are consequently greater than in other regions. In support of an igneous origin for these materials, which are supposed on such theories to have been intruded as bosses, or to have formed overflows at the time of the accumulation of the associated strata, have been cited particularly: (1) an irregularity of contact of the ore and jasper with the adjoining schists; (2) the projection of stringers of ore and jasper into the adjoining schists; (3) the induration of the adjoining schists; (4) the curvature of schistose cleavage by ore intrusions; and (5) the occurrence of fragments of the ore and jasper in an immediately overlying quartzite of the same series, this indicating their existence in their present conditions of induration prior to the accumulation of this quartzite.* On this theory the lamination of the ore and jasper is taken to be probably a fluidal structure, and the interbedding of ore and jasper with other schists to be the result of a contemporaneous flowing of lava. Having carefully examined the localities cited by the last advocate of an eruption theory as proving the above facts, I feel able to say that the occurrences, save the last named (5) are mainly trivial matters occurring within the space of a few inches, or feet at most, and that all are more easily explicable—as irregularities in original deposition, as irregularities due to the crumpled condition of the strata, or, and this chiefly, as due to infiltrations of iron oxide and silica into cracks in the rocks, and the replacement of rock material by such substances—on theories of original sedimentation of the iron beds than on those of an eruptive origin. The last named point, viz: the occurrence of fragments of the banded jasper in the immediately overlying quartzite, deserves more consideration, since it certainly indicates that, to some extent at least, these substances had reached their present condition at an early day. But cooling from a state of fusion is not the only way of reaching rapidly the indurated condition, and a former fused condition seems to be negatived at once by the nature of the material—quartz and iron oxide.

My own acquaintance with the ferruginous schists and iron ores of the Lake Superior region began, fortunately for me I think, in the Penokee country of northern Wisconsin, some thirteen years since. I say fortunately, because from the unfolded condition of the strata of the region most of the confusing appearances which have baffled so many in the better known Marquette district are eliminated here, while the formations and the ferruginous rocks are manifestly the same in both regions. What I saw in the Penokee region during the succeeding

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* See M. E. Wadsworth in Bull. Mus. Comp. Zool., vol. vii, No. 1.

three or four years served to convince me, not only that the ore and banded jasper-schists of the region are derived from a deposit of some sort, of sedimentary origin, but that several other forms of ferruginous rocks—viz: various schists composed of magnetite and quartz; of magnetite, hematite and quartz; of magnetite, actinolite and quartz; of magnetite, actinolite, quartz and carbon; of magnetite, actinolite, garnet and quartz; and also various cherty (the silica partly chalcedonic) ferruginous rocks banded with magnetite—must have had a common origin with the ordinary ore and jasper, since all are intimately associated parts of one continuous belt, which was traced at the time a distance of forty miles or more. None of the writers on the present subject seem to have appreciated that any explanation of the origin of the iron ores must include also, not only the jaspery schists, which are particular associates of the ore in the Marquette region, but also the long list of ferruginous rocks above named; though Julien appears to have covered the relatively unimportant garnetiferous rocks with his mechanical sedimentation theory.

The foregoing paragraphs present the condition of the question as it stood in my mind at the beginning, in 1883, of the investigations in the Lake Superior region of which I now have charge. I was strongly impressed with the inadequacy of any theory of an eruptive origin for any of these materials; but, while realizing that the true theory must begin with sedimentation, I had no more definite conception than this, all the explanations that had been advanced seeming unsatisfactory, or at least insufficiently supported. In what follows I draw on the results of my later studies, which have been extended in the years since the early summer of 1883, over all the areas in the Lake Superior country in which the ferruginous rocks occur; during which time also several hundred thin sections of the various ferruginous rocks have been made and studied in detail. In this microscopic work I have had the constant assistance of Professor C. R. Van Hise, who has prepared a full description of each section examined. Many theories during this time have presented themselves to me and my assistants, but none have been held heretofore more than very loosely, each to be set aside in turn as new and destructive facts were gathered.

Early in the study, however, it became evident enough—since as already intimated, some of the beds of ferruginous material have yielded fragments which have entered into the composition of the immediately overlying fragmental deposits, forming part of the same series—that any satisfactory explanation must provide for the fact that these materials reached their present indurated and silicified condition, in some cases at least, before the production of the next overlying layer of the series. It was soon seen, too, that a further proof of this early induration—although it does not necessarily set the induration so far back—is afforded by the extraordinary crumpling, shattering and brecciation which some of the jaspery and cherty ferruginous schists show where the formations containing them are folded. The adjacent rock beds, while often folded closely, show no signs of having offered so great resistance to the folding process. Relatively great induration antecedent to the folding process being thus demonstrated, the view ordinarily held by those who maintain for these materials some sort of a sedimentary origin, viz: that they have reached their present conditions by a regional metamorphism accompanying the folding of the series, seemed to have no standing ground. Many other considerations, moreover, led to the same conclusion. Among these I may mention the fact that these same ferruginous materials occur in formations in the Lake Superior country which are quite without folding, and which our later researches have demonstrated to be free from anything like a genuine metamorphism, using that term in the sense of a more or less thorough molecular rearrangement and recrystallization *in situ*. Indeed, among the folded iron-bearing rocks themselves we find but little if any indication that a genuine recrystallization has taken place. The quartzites, greywackes, etc., of these formations retain to the full their original fragmental structure, and, even in the case of the mica-schists, the changes that have taken place are often demonstrably of a metasomatic nature only. It seems difficult, therefore, to understand how a metamorphosing process, which could leave the fragmental texture in the adjoining rocks still recognizable, could yet have so greatly altered the iron-bearing layers. Again, the silica, which frequently forms so prominent a part of the ferruginous schists, and which is at times jaspery, but is far more frequently cherty or even chalcedonic—a point hitherto quite unrecognized in publications on this subject—presents every evidence, both in the thin section and in the field, of a chemical origin. In the thin section—in that it shows ordinarily no trace of a fragmental texture, even when relatively coarse-grained, and in that it approaches more commonly to the peculiar chalcedonic or even amorphous forms known to occur only with silica deposited directly from solution; besides which it traverses and follows the banding indifferently and in such a manner as to place its secondary nature beyond all doubt. In the field—in that the jaspery or chalcedonic silica, while in the main closely interbanded with the more ferruginous portions of the rock, is seen also to intersect the bands, or even to appear in the shape of a cement to a brecciated mass of fragments of the interbanded materials. All theories of a formation of these ferruginous rocks by metamorphism, or recrystallization *in situ*, from some sort of sedimentary deposit, seem to regard the jaspery or cherty material as representative of a fragmental siliceous ingredient in the original deposit—either a quartz sand or a fine "siliceous silt." On these theories this substance has been recrystallized from the fragmental condition. The facts above cited refute any such explanation, and prove incontestably the chemical origin of the silica. We may cite in addition, moreover, the fact that in these siliceous iron rocks themselves there is at times an admixture of fragmental quartz, which in the thin section is always sharply defined as an original ingredient and easily distinguishable from the water-deposited silica. The latter is frequently identical with that cherty material which has often taken the place of large bodies of limestone among the unaltered formations.

These considerations leading to the rejection of a metamorphic origin for any of these materials, as others had previously led to the rejection of an igneous origin, it followed that we were thus restricted to some theory which should account for the precipitation of most of them essentially in their present conditions, with perhaps some slight internal rearrangement; or to one in which the production, from some form of sedimentary deposit, of the conditions now obtaining, should be assigned to metasomatic processes, carried out, in part at least, at a very remote period. Lack of any definite evidence as to what might have been the original condition of these deposits led at first to a preference for the former of these views, though no such theory was ever held more than tentatively. One great difficulty with any such view seemed to be the want of any modern phenomena from which might be derived the data necessary to form any clear conception of the process. While we have, perhaps, in the deposition from some modern siliceous springs, a slight analogy to the interstratification of iron sesquioxide and silica, this analogy is, after all, but slight, and any theory of deposition from springs fails entirely to secure in its support any modern analogues for the various magnetitic and actinolitic schists whose production must be explained. Again, there is nothing in the structure of these deposits to indicate spring deposition, and everything to indicate deposition in bodies of water. But of the formation of such deposits by chemical deposition in bodies of water we certainly have no modern instances. Yet another difficulty seems to lie in the necessity, under this theory, of separating the jaspery and cherty silica into two parts, the main part having been deposited chemically with the original sediment, and a smaller part having infiltrated subsequently. But that essentially all the silica had had a common origin became more and more evident as the work progressed.

Later, as further study developed the fact that the least altered forms of the ferruginous schists contain a considerable proportion of some carbonate—the amount of carbonate increasing inversely with the amount of disturbance and alteration—the idea of a possible formation of these rocks by chemical deposition approximately in their present conditions gave place to views which included the idea of a replacement of some rock, originally dolomitic or calcitic, by siliceous and ferruginous substances. These latter views received considerable support by the discovery by Professor Van Hise that in the Penokee region certain regularly bedded hematites could be traced directly into one of the carbonate-bearing beds above referred to, the thin sections showing the gradual replacement of the rhombohedra of the carbonate by the red oxide of iron. That the original carbonate was itself ferruginous was an idea that had presented itself, but had been abandoned. But a suggestion from Professor Pumpelly led to a further chemical examination with regard to this point in which much new material was included. The result was the establishing the general ferriferous character of the original carbonate; while further quantitative analyses made in the chemical laboratory of the U. S. Geological Survey showed that it is often even a genuine siderite, though magnesian. This point once established, all of our field and laboratory observations seemed to fall suddenly into line and to establish the truth of an hypothesis long since advanced, viz: that these ferruginous rocks were once carbonates analogous to those of the coal measures; though the advocates of this hypothesis can hardly have realized the ground it could be shown to cover, and they certainly did not have any conception of the nature of the altering process.

The facts that have led us to this conclusion can of course be presented, in an article like the present one, in a general manner only, though the details are often of importance to the result.

The ferruginous rocks of the Lake Superior region may be conveniently separated into two classes, viz: those that occur in unfolded formations, and those that occur in formations more or less folded. Into the first of these groups fall the north-dipping iron-bearing beds of the Penokee-Gogebic series on the south side of the lake, in Wisconsin and Michigan, and those of the south-dipping Animiké series, on the northern side of the lake, in Minnesota and Canada. Into the second group fall the ferruginous rocks of the Menominee and Marquette regions, in Wisconsin and Michigan; and those of the Vermilion Lake region, and thence northeastward, in Minnesota. This classification of formations has no chronological significance; but the separation is a convenient one in the present connection, since the processes of alteration have been carried furthest among the folded rocks. Indeed, we find that the amount of change has been somewhat in proportion to the degree of disturbance that the rocks have undergone. Beginning with the flat-lying Animiké series, we find the largest amount of unaltered material; next in order come the highly tilted but unfolded Penokee rocks; then the moderately folded Menominee and Marquette formations; and, finally, the closely folded rocks of the Vermilion Lake district. It is not to be supposed, however, that the series of changes is only made out by putting together the rocks from these separate districts, the alterations for one district beginning where those of another leave off. On the contrary, we find in the flat-lying Animiké nearly all the changes, only less thoroughly carried out. In the Penokee series the changes have been more general and are pushed a little further, but some of the original material is still remaining. Similarly among the folded rocks we find the changes pushed to their extreme, there being but mere remnants of the unchanged material. Each of these four series of rocks we may now consider in order.

The northern edge of the so-called Animiké series, whose beds range in position from approximate horizontality to a southern dip rarely exceeding ten degrees, runs from the northern side of Thunder Bay, Canada, west and south to the national boundary line, in the vicinity of North and Gunflint lakes. Thence it extends into Minnesota but a short distance before it is overlapped and the Animiké buried from sight, by an immense spread of the coarse olivine-gabbro which lies at the base of the Keweenawan Group in that region.* Sixty miles farther southwest, in the vicinity of the so-called Mesabi Range, Minn., the northern edge of the Animiké reappears, remaining uncovered by any newer formation, other than the drift, at least as far west as the vicinity of the Mississippi River, an additional distance of over eighty miles. West of the new railway to Vermilion Lake, however, the rocks are badly concealed by the glacial drift, and this portion of the Animiké is but little known; but the remainder of its northern edge, along a total distance of over eighty miles, has been examined at a

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* The existence of this most interesting overlap, announced here for the first time, has been established mainly by the researches of Messrs. W. N. Merriam and W. M. Chauvenet of the U. S. Geological Survey.

number of points. Throughout most of this distance, the basal beds of the series, or at least the lowest beds in sight, are highly ferruginous and include nearly if not quite all of the lithological kinds with which we are now concerned. At some points but one or two of the kinds are to be seen, but at others most of them occur together in intimate association, and the whole appearance is such as to render in the highest degree probable a common origin for all the phases; a probability which is carried to demonstration by a study of the thin sections, which present us with complete gradations from the unaltered carbonates to cherty and jaspery materials, and even to actinolitic magnetite-schists.

A fine showing of the least altered form of these ferruginous rocks is to be seen on the Kaministiquia River, at Kakabika Falls, Canada, where there are black slates interbedded with bands of dark-gray to light-gray carbonate. Complete analyses of these two varieties, made in the laboratory of the Geological Survey, show a content of siderite ranging from 35–45 per cent. The fact that even the black slate contains at times as much as forty per cent of siderite in the mass of the rock certainly seems to prove, as does the whole appearance of the large exposure, the original character of the carbonate. In both places carbonaceous matter is present, the content of carbon in the black slate reaching 3·54 per cent. Besides the carbonate and organic matter, there are present clayey material, a small quantity of magnetite, and a considerable quantity of silica. The latter is present to a slight extent as fragmental quartz, but a very much larger part has evidently separated out in its present position. This ranges from a mosaic of finely crystalline quartz, through chalcedony, to amorphous silica. Most of this silica is manifestly of a secondary origin, but some of the more amorphous material may date from the original solidification of the rock.

The showing on the northern sides of Gunflint and North lakes, on the national boundary line, is, however, of much greater interest in the present connection. Here the alteration has been carried much further, and bands of the carbonate are found interleaved with seams of magnetite and others of a chalcedonic to cherty silica, and still others of a jaspery material, in which case bands of specular iron are included within the jasper. On the northern side of North Lake this jasper reaches an immense development, forming bold cliffs facing to the northward. The magnetitic slates on Gunflint Lake are highly charged with actinolite and tremolite, and a study of the thin sections seems to make it manifest that all of the varieties have proceeded from a silicification of the carbonate, every stage of the transition being met with from the carbonate to clear chert and chalcedony, or to jasper—which is simply a finely crystalline silica stained with red oxide of iron—or to the magnetitic slates. In the latter case there is supposed to have been a reaction between the carbonate and the silica as a result of which the iron of the decomposed carbonate, having been partially oxidized, has separated out as magnetite, while the magnesia, demonstrated by analysis to be present in the carbonate, entered into union with the silica to form tremolite and actinolite. The excess of silica has separated out as the crystalline to chalcedonic material which everywhere pervades these magnetitic slates. A very fine magnetite dust is found present as an inclusion in the unaltered carbonates, and along with the organic matter which stains certain bands of the carbonate, but the bulk of the magnetite is certainly secondary. Lest the original character of the carbonate involved should be questioned, I may say that all appearances in the thin section and in the field prove it to be the oldest mineral present. Thin crossing veins of a secondary siderite and dolomite are to be found, but the stratiform carbonate is manifestly original.

The iron-bearing beds of the Mesabi Range above alluded to show essentially the same association of materials. Magnetitic and actinolitic cherty substances have there again a very considerable development, and have even attracted a good deal of attention from the iron miner, although as yet without satisfactory result.

It should be said that, while these iron-bearing beds of the Animiké series have in general the flat-lying position above indicated, there are, nevertheless, points at which they show sudden and somewhat violent disturbances, suggestive of movement along the contact line between this formation and the granite to the north of it, and there seems to be a connection between the amount of alteration and the presence of these disturbances, the greatest alteration having been noted where the disturbances occur. At the same time I am not as yet prepared to say that there is a necessary connection between these facts.

As already indicated, the strata of the Penokee region on the south side of Lake Superior dip to the northward, the angle being generally quite a high one, more often over, than under, 60 degrees. The iron-bearing horizon of this series lies in its lower portion, and near its southern limit,* and is the counterpart, in character and stratigraphical position, of the iron horizon of the Animiké series.

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* See Geol. Wisconsin, vol. i, pp. 80–95; vol. iii, pp. 100–101. See also this Journal, March, 1885, pp. 236–249. With the latter paper is a small map showing in a compact form the position and general relations of the ferruginous horizon.

In the easternmost portion of this iron belt, the ferruginous schists composing it are largely actinolitic magnetite-slates, and the same is true of all of its western portion, that is to say, of all that portion west of the Potato River, though occasionally a jaspery tendency is noticed. In the interval between these two portions, however, the rocks of the belt are of somewhat different character, although belonging to the same horizon with, and being actually continuous with, the actinolitic magnetite-schists. This intervening portion, along a distance of some thirty miles between the Potato River in Wisconsin and a point about four miles west of the Little Presqu' Isle River in Michigan, shows as the prevailing rock a stratiform cherty material, portions of which are magnetitic but without actinolite, so far as our sections have yet revealed. Other portions show jaspery layers in considerable developments, while at a number of points on both sides of the Michigan-Wisconsin boundary workable deposits of a rich hematite ore have been opened. But the most interesting feature of this belt lies in the occurrence within it, and grading into the other materials constituting it, of an iron carbonate, closely analogous to that above described as occurring at a similar low horizon in the Animiké series. Like the carbonates of the Animiké series also, it is manifestly the least altered of the rocks of the belt and the nearest to the original condition. Its gradations into the various cherty and jaspery portions of the belt, and also into the hematite beds mentioned above, render it evident that these are derivatives from it, a conclusion which is wholly borne out by the appearances presented by the thin sections. With this unaltered carbonate are at times small quantities of magnetite, which is mingled so intimately with the mass that its original character seems possible; but, as in the case of the Animiké iron horizon, the main part of the magnetite here seems also to be secondary. It should be said also that here, as in the case of the Animiké, gradations are observable into a fragmental black slate both from the actinolitic and magnetitic kinds and from the cherty carbonates. It should also be said that at one place on the Penokee range, near the passage of Bad River, there is, forming part of and grading into the actinolitic magnetitic slates, a garnetiferous slate composed mainly of actinolite, garnet, quartz and magnetite. The relation here is so intimate as to render evident a community of origin between the garnetiferous and non-garnetiferous kinds.

It will thus be seen that the occurrences in the Penokee region are strikingly like those of the Animiké iron horizon and that here as there there is strong evidence that all of these ferruginous rocks have been derived from original carbonates by metasomatic processes; the only differences being the greater extent to which the alteration in the Penokee series has been carried out, and the occurrence in it of a garnetiferous rock not met with as yet in the Animiké series.

The iron-bearing series of the Menominee region, which lies on both sides of the Menominee River, the boundary between northeastern Wisconsin and Michigan, is folded so as to place the rock belts for the most part in an approximately vertical position. There does not seem, however, to have been the closeness of folding so noticeable in the Vermilion Lake region of Minnesota. The most abundant of the ferruginous rocks of the Menominee region are cherty schists charged in varying quantities with magnetite, or hematite, or both, and even with the brown oxide of iron, and containing varying quantities of an iron carbonate. These schists graduate into and include carbonaceous and graphitic slates, just as in the Penokee and Animiké formations, and when studied in the thin sections are seen plainly to be merely a repetition of those met with on a large scale in the eastern portion of the Penokee range, from which they differ chiefly in the highly contorted condition which they show in places, while in others they are relatively free from such contortions. These contortions have no parallel in the adjoining layers, and often seem to have little relation, in axial directions, to the general system of folding of the strata. They are taken to indicate the relatively great resistance to folding offered by these schists, on account of the silicious induration they received prior to the folding process. When these contortions are wanting, the similarity between much of the Menominee ferruginous schist, and the Gunflint beds of the Animiké series amounts to an identity of characters. The iron carbonate, whose presence in these schists is often indicated by the rusty brown weathering, occurs in very varying proportions, but is manifestly an original ingredient. Actinolite is present, in some kinds, and the thin sections demonstrate the derivation of all phases from an original carbonate. The siliceous matter of these schists is more commonly cherty* or flinty than jaspery, but at times it takes on a jaspery aspect for considerable areas. Although we do not here meet with such extensive masses of jaspery material as are found in the Vermilion Lake and Marquette regions, nevertheless, the community of origin of the jaspers of the Menominee region with those of the two latter regions is sufficiently manifest, although there are some peculiarities in structure and arrangement among the Marquette and Vermilion Lake jaspery schists

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* The term "chert" is used in this article to cover colorless, white, or grayish hornstone-like silica, which under the microscope is either wholly crystalline, or partly crystalline and partly chalcedonic, or even amorphous.

which are to be subsequently noted. The iron ore bodies of the region lie within these cherty schists, not in lens-shaped masses around which the schist bends, but in irregular bodies directly in the course of the schistose banding, or in more definite layers within the schist, and seem to have arisen from two causes, or from a combination of them, viz: from direct oxidation of the bands of the carbonate in place and from the deposition within the schist, from percolating waters, of oxide of iron. In short, we have, in this region, except that no considerable body of unsilicified carbonate has as yet been met with, all of the indications found in the Animiké and Penokee formations, of a derivation of both ferruginous rocks and iron deposits by a process of silicification from stratiform shales impregnated with carbon and iron carbonate.

The differences between the ferruginous horizons of the Marquette and Menominee regions appear to lie chiefly in the greater development in the first-named region of the jaspery schists, and in the prevalence in it also of more thoroughly crystalline ores, which are chiefly specular hematite, but also in minor degree magnetite. In addition to the contortion of the jasper-schist, which is at times carried to an extreme, there is often to be seen in places evidence of a more or less complete shattering and brecciation, in which cases the substance filling the interstices may be specular iron alone or specular iron along with jaspery or cherty silica. This is a phenomenon which is met with in yet more striking development in the Vermilion Lake region. It should also be said that in portions of the Marquette region there are developments of actinolitic magnetite-schists which are somewhat different, in habit at least, from the usual actinolitic magnetite-slates already described, which occur in abundance in this district also. But notwithstanding these differences the chief ferruginous horizons of the Marquette region have manifestly had an identical origin with those of the Menominee and Penokee districts. Not only do they show all of the lithological varieties met with in these regions, but at the same time they present equally strong evidence of a sedimentary origin. This is particularly the case in those portions of the series which are least crumpled and disturbed, in which case there is often no more alteration than in the iron belt of the Penokee series, while for long distances there is an equally simple structure.

Our material from the Marquette country is unfortunately not as abundant as I could wish. All of the principal localities have been visited and somewhat carefully examined, but the collections made at the time of these visits have since all been destroyed by fire. A number of the thin sections made from these specimens before the fire have, however, been saved, and these, with the field notes, and with the aid of a number of specimens for which we are indebted to the kindness of Dr. C. Rominger, suffice to establish the general identity of the Marquette ferruginous schists with those of the districts previously described, and to enable us to recognize the various stages in the process of silicification. While there are certain portions of the district from which our material is very scanty, or, indeed, wanting altogether, and while we think that there can in the main be no question as to most of the developments of ferruginous material, there are certain kinds, as for instance some of the coarser-grained actinolitic schists, as to whose relation to the other ferruginous materials we feel now unwilling to speak. We feel also that our knowledge as to the structural relations of certain of the ore beds, more particularly some of the magnetite bodies, is insufficient to allow us to speak too confidently as to their origin. A good many of the ore bodies, and more particularly some of the so-called soft hematites, appear to have resulted, partly at least, from a direct oxidation of the iron carbonate of some of the cherty schists. In other cases the ore bodies owe their origin and general shape, we think, to processes of infiltration and replacement.

The iron ores and associated ferruginous schists of the Vermilion Lake country occur in a belt of schistose rocks which, bounded north and south by belts of granite and gneiss, emerges from the general drift-covering of northeastern Minnesota not many miles west of Vermilion Lake and pursues thence, a general northwesterly course to the national boundary line in the vicinity of Knife Lake. The schistose rocks of this belt have, as a rule, an approximately vertical position, the folding having been close to a degree unparalleled in the iron-bearing rocks south of Lake Superior. Small portions of this belt, including the ferruginous schists and iron ores, present characters which are practically identical with those of portions of the iron-bearing formations of the several other regions already passed in review. On account of this identity, and because also there are some strong reasons for suspecting an unconformity between them and the larger part of the schistose rocks of this belt, which are quite different in character, the iron-bearing portions of the belt are supposed to belong with the other iron-bearing formations of the Lake Superior country.

The ferruginous materials are exposed at a number of places along the course of the schistose belt, but so far as is now known, they reach their greatest development in the vicinity of the south shore of Vermilion Lake. Here are immense exposures, rising in considerable measure into bold hills, of two principal kinds of ferruginous rocks, viz: a black to dark gray ferruginous schist, and a bright red, banded jaspery schist. These two kinds occur in part in distinct exposures, but also occur most intimately mingled. In fact, between the two there are such intimate associations and such minute gradations, that a general community of origin is entirely manifest. In this connection it should be said, however, in order to avoid possible misunderstanding that there are here also, interbanded with the ore belts, light-colored schists of a totally different character from those now referred to. Between these light colored schists and the ferruginous materials no gradation is observable. The dark-colored schists are carbonaceous, at times so highly so as to present a graphitic appearance. They are very commonly banded with a light colored to perfectly white, cherty silica, which is minutely crystalline or even chalcedonic, and which even to the naked eye is most manifestly a result of the secondary process of silicification; for, while commonly occurring in bands parallel to bedding of the rock, this cherty material will frequently break across the lamination, forming a system of interlacing veinlets between which are patches of the white-and-black-banded material. Equally evident is it in the field that the jaspery silica here is identical in origin with the whiter more chalcedonic form; for not only do we find all stages of passage between the two forms of the silica, but often in the most completely jaspery forms the minute but strongly marked sedimentation films of the original slaty rock are repeated in lighter and darker colored bands in the jasper itself. Indeed the transition from this laminated jasper to the dark-colored slate may be seen to occur within the distance of a few feet at most. Equally with the white form of the silica do the most jaspery forms occur in traversing bands or veins. The ores, which are, so far as now known, wholly specular, are found associated with the jasper schists often in large bodies, but in the most irregular forms, at times grading into the banded jasper-schist, and again traversing it in sharply defined tongues, or bodies of most irregular outline. It is rarely that the relation of the richer ore to the leaner jaspery material can be so well realized as at this place; for here we have the unusual case of great smoothed and glaciated surfaces upon which the contrasts between the steely ore and the bright red jasper are most strikingly displayed, and the relations of the two thus made far more evident than is generally the case in the openings made in mining.

The phenomena which have been appealed to to prove an eruptive origin for the ore and jasper of the Marquette region are yet more strikingly displayed here, for here the regularly banded and contorted jasper may be seen traversed, not only by tongues of ore, but by seams of jasper and of jasper and ore together in every conceivable shape. Unfortunately for the theory, however, the same exposures give, in the gradation of the whole rock mass into manifestly sedimentary slates and in the manifest community of origin between the white purely quartzose silica and the jaspery material, conclusive arguments against any such hypothesis. In places where the folding has been most violent the rock is often shattered, as it is seen to be in the Marquette country, but to a far more violent and striking degree, and in these shattered portions the cementing material may be ore, or jasper, or ore and jasper together, or the whiter chalcedonic silica. It should not, however, be understood that these brecciated and veined portions form any very large proportion of the whole exposure. In the main it shows the regularly laminated though often highly contorted jasper. It should be said, in connection with the matter of the gradation above said to obtain between the jaspery schists and the gray carbonaceous slates, to avoid possible misunderstanding, that there are here also, interbanded with the ore belts, light-colored schists of a totally different character, between which and the ferruginous materials there are no gradations.

If no microscopic work had been done and if no evidence to the same effect had been collected in other portions of the Lake Superior region, these exposures alone would be sufficient, I think, to establish the formation of the jasper-schists from some sort of sedimentary slaty rocks by a process of silicification. This conclusion is borne out very thoroughly by the appearances of the thin sections, which in addition furnish us with quite striking evidence of the nature of the original material. The darker-colored slates are found in their least altered conditions to contain a considerable quantity of iron carbonate. This presents itself, not merely in detached individuals in the ground-mass of finely divided interlocking silica, but also in areas of considerable size. These areas are aggregates of the crystalline or rhombohedral carbonate, and are most manifestly the oldest portions of the rock. The larger patches, in which, it should be said, the carbonate is at times more or less mingled with carbonaceous material, have evidently been separated from one another by the interlacing seams of silica; while from them to single rhombohedra, lying isolated in a ground mass of silica, the carbonate is present in pieces of every size. At times this rhombohedral carbonate has been changed directly into sesquioxide of iron; in other cases, however, it is mingled with actinolite, magnetite and silica in such manner as to suggest that the two former minerals have resulted from it by virtue of a lower degree of oxidation and the combination with silica of some of the iron, along with the accompanying magnesia of the carbonate, to form actinolite. These actinolitic magnetite-slates, it should be said, also often contain carbon, and the idea is suggested at least that this carbon has had to do with preventing a more complete oxidation of the iron. The silicification process has, however, in large measure, removed the iron of the carbonate completely and such iron has passed off in solution, to be concentrated in other portions of the mass in the shape of seams or bodies of the sesquioxide.

The facts summarized in the foregoing paragraphs appear to lead of necessity to the following conclusions:

(1.) The original form of the beds of the iron-bearing horizons of the Lake Superior region was that of a series of thinly bedded carbonates interstratified with carbonaceous shaly layers, which were also often impregnated by the same carbonate. This carbonate was generally more or less highly ferriferous, though probably there were intermediate forms between it and dolomite. With these unaltered layers there seems to have been some little magnetite, in the shape of a fine dust mingled with the carbonaceous impurities, but most of the magnetite now found is taken to be secondary. Such a series of layers finds parallels in the carbonates of the coal measures,—which present us, in some cases, with bands of an iron carbonate interstratified with carbonaceous seams—and in such bedded carbonates as those on the east side of the Hudson River, about six miles below Hudson, N. Y. With these latter ores also there is much carbonaceous matter in bands. The so-called black band ores of the coal measures are also at times very close in appearance to the black slaty ferruginous layers of the Animiké series.*

(2.) By a process of silicification these carbonate-bearing layers were transformed into the various kinds of ferruginous rocks now met with in this region. The silicification varied in degree from those cases where a few thin seams of silica traverse the otherwise unchanged rock, or follow its lamination, to those in which there was a complete substitution, the iron being wholly leached out, in which case the lighter-colored cherty forms were produced.

(3.) The iron thus removed from the rock at the time of silicification passed into solution in the percolating waters, to

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* Moreover, these similarities are not macroscopic only, but extend also to the thin sections, a large number of which have been made for comparison from coal-measure ores, and from the Hudson ores above mentioned.

be redeposited in various places as it became further oxidized, thus making ore bodies and various impregnations, and again forming the coloring matter of the jasper, the finely interlaminated hematite of which is taken to be mainly the result of a secondary infiltration following the banding of the original rock, though we may imagine the hematite bands to have formed at times by direct oxidation from iron carbonate seams.

(4.) In other places, however, instead of leaching it out more or less completely, the silicifying waters seem to have decomposed the iron carbonate in place, producing a magnesia-silicate, or a magnesia-iron-silicate, the excess of iron oxidizing imperfectly and separating out as magnetite, and the excess of silica crystallizing finally as a minutely interlocked quartz ground mass. Thus have arisen most of the actinolitic magnetite-schists. The various intermediate forms met with between the magnetitic and jaspery or cherty hematitic schists may be explained by the carrying out simultaneously of the processes of removal of the carbonate and of its decomposition in place.

(5.) The bodies of rich ore have probably had different origins in different cases. Some of the red hematites seem to have resulted from a direct oxidation in place of the original carbonate. This is demonstrable in the cases of some of the thinner seams of hematite by the retention of the crystalline form of the carbonate, but most of the red ores and specular ores, between which there are many gradation varieties, seem rather to be the result of the concentration of the iron by leaching. It is quite noteworthy that, except in the case of certain magnetite mines, all the ore bodies are associated with great developments of jaspery or cherty silica, or both; i. e., they occur where the silicification has been most thorough, and where there has been the greatest amount of leaching of the iron carbonate. Some of the magnetite mines appear to be working on what are merely richer parts than usual of the magnetitic schists; but there are other cases of magnetite deposits, as also of deposits of specular ore, for which I do not now see any satisfactory explanation, though the difficulty comes chiefly, I suspect, from lack of sufficiently close acquaintance with them.

(6.) Some of the silicifying process went on before the folding of the formations; but some also afterwards, and to the latter period appear to me to belong the larger bodies of crystalline ore, the crumpling and shattering of the layers affording the best conditions for the action of the silicifying waters.

It is not supposed that the theory thus advanced will not require modification in the future. Such a necessity is to be expected, and modifications, even to complete abandonment, will be made to the full extent that any newly obtained information may direct. It is recognized, too, that nature's methods are multiple and complex, similar results proceeding from very different causes; and it is not designed to say that the theory covers *all* occurrences of ferruginous rocks in the Lake Superior country. For instance, we have found rocks composed of quartz, actinolite and magnetite to have been derived from the alteration of an olivine-gabbro of the Keweenaw series. These actinolitic rocks are very different in habit, however, from the actinolitic magnetite-schists above alluded to, but still the existence of such an alteration admonishes us that similar changes may have taken place more widely than is now suspected.

Nevertheless it is thought that in its main features the theory now presented will stand. It has this in its favor, at least, that its author has not been impelled to it by any preconceived notions—such ideas as he had having been much more opposed to such an hypothesis than in its favor—but has been led to it very gradually during the growth of an experience with these singular substances, which, in extent of territory covered, and in abundance of material examined, probably no other geologist has had the opportunity to obtain.

Washington, D. C., March, 1886.

ART. XXX.—*Further Notes on the Artificial Lead Silicate from Bonne Terre, Mo.;* by H. A. WHEELER.

IN the number of this Journal for August, 1885, there are some crystallographic determinations and analyses of both the crystallized and massive types of this artificial mineral from the Desloge Lead Co., of Bonne Terre, Mo.; by E. S. Dana and S. L. Penfield. Since then I have had an opportunity to examine some specimens in the metallurgical collection of Washington University of this interesting material. The metallurgist of the Desloge Co., Mr. J. T. Monell, who forwarded the above specimens, informs me that the crystals were found directly under the hearth of an old Freiberg or reverberatory roasting furnace, close to the fire-bridge. The ore of this company, which is exclusively galena, is all treated, preparatory to smelting in a water-jacket furnace, to a preliminary roasting. Silica, to the extent of 10 or 12 per cent, is added to the roasting charge, and the heat is carried sufficiently high, at the latter part of the roasting, to agglomerate and melt the charge by the time it reaches the fire-bridge. It was directly under this fusion hearth of the furnace that the crystals of the lead-silicate were found as linings of irregular cavities. The gangue of the ore is a magnesian limestone, which though mostly removed by dressing, is still present in appreciable quantities in the roasted ore and shows in the analyses. Associated with the galena is more or less pyrite, and a very small but persistent amount of nickel and cobalt; especially the former, probably as siegenite, though it is generally not to be detected by the eye.

My examinations, as far as they go, largely confirm those of Dana and Penfield. In one group of dark-red crystals, of rather feeble lustre, the individual members measure from 30 to 40^{mm} in length and thickness, and their analysis is given below. Another group of crystals furnish dimensions of 8 to 15^{mm}, while they have a highly vitreous luster and are of a clear brownish-red color. They all seem to consist of one type of crystal, that is generally very perfectly developed, made up of two trigonal prisms and the basal pinacoid. One of the trigonal prisms is largely developed and is very prominent, while the faces of the other trigonal prism are much smaller and in some cases are scarcely apparent. The fracture is decidedly resinous and the streak yellow, while the hardness is 3.

Analyses of the large, dark, translucent and the small, clear, light colored crystals are herewith appended, which agree with those of Penfield in showing that it is essentially a lead silicate. The finely disseminated magnetite alluded to by Penfield I also found, but removed it, after finely grinding in an agate mortar, with a magnet. It probably comes from the scales that drop off from the iron tools that are so freely used at the fusion stage of the roasting process.

	Coarse Crystals.		Fine Crystals.
SiO_2	17·11		18·51
PbO	73·66		72·93
Fe_2O_3	0·80		1·31
Al_2O_3	0·53		0·62
CaO	2·35		1·66
MgO	0·22		0·20
Cl	0·08	5·36%	undet.
Na_2O	2·22		"
NiO	3·06		"
	100·03%		95·23%

In the analyses given by Penfield, the iron is given as FeO; as it plays so small a part in the composition, while the color of the specimens are all either red or brown, no special examination was made to determine the condition of the iron and it was assumed to be in the form of Fe_2O_3.

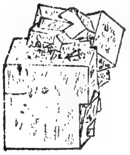
Department of Mining and Metallurgy, Washington University.

ART. XXXI.—*Limonite Pseudomorphs after Pyrite;* by JOHN G. MEEM.

SEEING an article in the May issue, vol xxxi of this Journal, on limonite pseudomorphs, it was thought that a short account of the pseudomorphs occurring in Rockbridge County, Va., would be of interest. These crystals are found on a hill sloping gently to a small stream (Hoffman's Run) about three-quarters of a mile southeast of Lexington, where they occur in the soil, on or near the surface, with outcropping limestones of the Lower Silurian age. In color they vary from a very light to a very dark brown, and in some cases are almost black. Some faces have a fine luster, others none at all. The pseudomorphs are hydrous and give a yellow powder, showing them to be limonite. Most of the crystals have undergone a complete alteration, there being no pyrite visible to the naked eye. In some, the unaltered pyrite is found forming a nucleus at or around the center; in others, it forms the bulk of the crystal, the latter then having only a coating of limonite. Bedded in the limestones from the same locality, unaltered pyrite occurs, though not in well defined or isolated crystals.

The forms of these pseudomorphs present some features worthy of notice. The most common is the octahedron. This generally occurs combined with the cube, and of these combinations we have every variety from large octahedral and very small cubic faces to the other extreme (see figs. 2, 3, 4).

One of the points of interest is noticed in the following. On nearly all the octahedral faces (1, Dana) striations running at right angles to the edges of these faces are observed (figs. 4, 5). Col. M. B. Hardin, Professor of Chemistry, etc., called attention to it and suggested that it pointed to a tendency in the crystal to form trapezohedral faces, that is, to an oscillation between the octahedron and trapezohedron. Observations were begun with the view to settle this if possible. Specimens were obtained in which the angles varied more and more from the octahedral angles, and in which the tendency to trapezohedral faces (*m-m*) was more marked, until finally some were found that had the faces (*m-m*) fully developed, the striæ obliterated and the edges very clean cut (figs. 6, 7, 8, 20, 21). In some of the faces (1) in which there are no striations observable, the angles are distorted from the true octahedral angles by a slight bulging at the center of the faces. Aggregations of these crystals are very common (fig. 1, example of cubes). In some of the crystals whose form is shown to be trapezohedral by projecting edges, this aggregation of the small trapezohedrons is carried to such an extent and in such a manner on the principal faces (*m-m*), as to present a general outline almost spherical, this outline being made up for the most part of apices of trapezohedral pyramids. In another spherical aggregation the projecting crystals are combinations of cubes and trapezohedrons, the faces of the latter in one or two of the crystals being perfectly developed, while in many of the other crystals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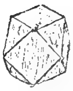
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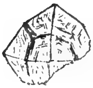
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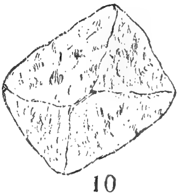
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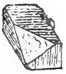
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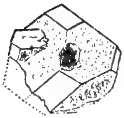
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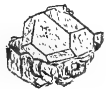
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the trapezohedrons are only filled out along the edges, making star-shaped figures around the cubic face (fig. 18). This depression of the faces (*m-m*) in some instances has encroached on the cubic face, making of it a star-shaped figure (fig. 19) but not like the other. Another aggregate has the exterior crystals very small, and its form is remarkably like that of an acorn and its cup. In some of the octahedrons the effect caused by the repeated interruption of the tendency to form the faces (*m-m*) on the face (1) is often quite striking, producing step-like formations (figs. 9, 11). Another point observed was that in some of the combinations of the cube and octahedron the faces of the latter were unequally developed, while those of the cube were elongated into rectangles (figs. 13, 22). It was found that the development took place in alternate faces of any half of the octahedron, that is, that the large and small faces alternated above and below, and it was also found that the cubic faces which were parallel were elongated in directions at right angles to each other. As elongation or distortion of the octahedron could not produce either of these effects, the conclusion is that the octahedron is composed of plus and minus tetrahedra, notwithstanding the fact that all the faces (1) are the same in general appearance. In this combination the edges of the tetrahedron whose faces are more largely developed are replaced by cubic faces. These faces (H) have luster, while the faces (1) have not.

The distortions occurring in these crystals produce singular effects (figs. 9, 10, 11). In some of the octahedrons, one of the axes will be so much inclined that a crystal is produced decidedly monoclinic in appearance. In others two axes are inclined, giving a triclinic appearance. Some of the cubes have been distorted into prisms apparently tetragonal or orthorhombic. One of the latter (fig. 12) has two of its diagonally opposite angles replaced by large faces (1), and the other angles by very small faces or none at all. In some of the crystals fossils are found (figs. 14, 15, 16, 17), sometimes in the crystal, sometimes on a face, the fossils being composed of limonite. Most of the crystals examined were obtained from Col. J. H. Morrison, Adjunct-Professor Chemistry, etc., who has collected them in large numbers.

Virginia Military Institute, June 12th, 1886.

ART. XXXII.—*Note on the hydro-electric effect of Temper, in case of Steel;* by C. BARUS and V. STROUHAL.*

OUR original object in writing these papers was that of elucidating questions having reference to the carburation of steel from a purely physical standpoint. The reasoning available to the physicist is, however, of an analogical kind, and therefore as dangerous as it is fascinating. Hence, in view of the time already spent, it seemed to us expedient to endeavor to

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* Communicated with the permission of the Director of the Geological Survey.

cut more nearly down into the heart of the inquiry and to determine directly the carbon relations of steel as a function of the temperature (0° to 400°; 400° to 1,000°) and of the time of annealing; to do this with full reference to the physical occurrences observed in the first and second phases of the phenomenon. So far as we know, M. Caron[*] alone has occupied himself with similar work; but his researches, being largely restricted to the extreme states hard and soft, are for the present purposes incomplete.

Glass-hard steel rods (Stubs) about $0{\cdot}1^{cm}$ in diameter and tempered uniformly in the way described elsewhere,[†] were each broken into four nearly equal parts and four samples of hard steel identical in composition and temper thus obtained. These samples were annealed at 20° (glass-hard), 100° 4^h, 200° 1^h, 360° 1^h, 1000° respectively. Having treated them with *cold* HCl, we found that the rods annealed at 20° and at 100° dissolved apparently without residue; those annealed at 200° left a trace of flocculent carbon. Rods annealed at 360° yielded flocculent carbon in some amount; rods annealed at 1000°, finally, a comparatively copious and heavy carbon precipitate. The residues were collected in a weighed Gooch crucible (asbestos filter), thoroughly washed in the usual way,[‡] dried, weighed, ignited in oxygen, again weighed, and the loss of weight on ignition estimated as carbon. The results thus obtained are sufficient for the present purposes:

Annealed at:	20°, ∞	100°, 4^h	200°, 1^h	360°, 1^h	1000°
Uncombined graphitic carbon per gram of steel, c =	<0·0007	<0·0007	0·0009	0·0021	0·0047

In a second series of similar experiments we found:

Annealed at:	20°, ∞	100°, 10^h	200°, 1^h	360°, 1^h	450°, 1^h	1000°, 30^m	Commercial (soft).
Uncombined graphitic carbon per gram of steel, c =	0·0001	0·0005	0·0005	0·0014	0·0009	0·0033	0·0053

In general c increases at an accelerated rate with temperature. The large datum for the commercial state, as compared with the smaller values of c for steel heated to redness in the ordinary way is an interesting feature of these results. We will refer to it again below. Temperatures even as low as 100° when acting on hard steel for long intervals of time (10^h) produce perceptible precipitation of the carbon in the steel.

On closer inspection it appeared that steel annealed at 100° is, *cet. par.*, more easily soluble than glass-hard steel; steel annealed at 200° more easily than steel annealed at 100°; steel

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[*] Caron: Comptes Rend., lvi, pp. 43, 211, 325, 1863.

[†] Bull. U. S. G. S., No. 14, p. 29, 1885.

[‡] Using dilute HCl, hot water, solution KOH, alcohol, ether. Cf. Blair, "Report of the Board of Testing Iron, etc.," Washington, Govt., I, 1881, p. 248.

annealed at 360° more easily than steel annealed at 200°. In other words, *generally*, the rate at which solution takes place increases as temper continually decreases. These curious results were substantiated by annealing one-half of short glass-hard rods (ca. 5^{cm} in length) at red heat. On dissolving in HCl, the diameter of the soft length is diminished more rapidly than the diameter of the hard length. The diminution is usually greatest near the middle of the rod, where hard and soft parts meet; showing, probably, that local galvanic action is here perceptible.* If we define the rate of solution as the mass dissolved per unit of area per unit of time, then in case of two submerged cylinders, for which during the time t the radii are reduced from ρ_0 to ρ and from ρ_0 to ρ' respectively, the rates, *cet. par.*, will be to each other as corresponding values of the expression,

$$-\delta\int_{\rho_0}^{\rho}\frac{2\pi\rho d\rho}{2\pi\rho}, \text{ or as } \frac{\rho_0-\rho}{\rho_0-\rho'}.$$

The following little table contains some of the results obtained with rods in the hard (h) and the soft (s) states respectively, dissolved in acid, HCl, under identical conditions. The rods are numbered A, B, C, D. These ratios of rates are of course subject to very large variations depending on the method of annealing, passivity, etc. The table is a fair exhibit of average values.

Rates of solution of hard and soft steel. Original diameter, $2\rho=0{\cdot}126^{cm}$.

	Diameter 2ρ=				Rate=				Mean Rate.
	A	B	C	D	A	B	C	D	
h	0·122	0·123	0·122	0·122	1·0	1·0	1·0	1·0	1·0
s	0·115	0·116	0·115	0·113	2·7	3·3	2·8	3·2	3·0
h	0·116	0·116	0·116	0·115	1·0	1·0	1·0	1·0	1·0
s	0·103	0·108	0·106	0·104	2·3	1·8	2·0	2·0	2·0
h	0·090	0·090	0·089	0·090	1·0	1·0	1·0	1·0	1·0
s	0·052	0·061	0·052	0·058	2·0	1·8	2·0	1·9	1·9
h	0·078	0·077	0·077	0·076	1·0	1·0	1·0	1·0	1·0
s	0·038	0·029	0·028	0·042	1·8	2·0	2·0	1·7	1·9

From these results we inferred that hard and tempered steel would probably be distinguishable hydro-electrically, and that for the first phase of the phenomenon of annealing, at least, this

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* It is also probable that steel annealed at a temperature in very low redness is more easily soluble than steel in any other state, hard or soft.

distinction might be more delicate than the estimation of precipitated carbon. To test this inference we selected rods Nos. 1 to 12, quenched uniformly glass-hard by our method. These were then broken in the middle and the first halves of each rod left in the glass-hard state; the other halves were annealed in pairs at 20°, 100° 4^h, 185°, 360° 450°, 1000°, respectively. In order to anneal these (long) rods uniformly, we used a special device by which they were drawn vertically upward, through a zone of constant temperature, by clockwork. If h be the height of this zone and ρ the radius of the disk or drum revolving once per hour, then $t=\frac{h}{2\pi\rho}$ is the time of annealing in hours. Again, if we make $h=2\pi$, then the time of exposure in hours is the reciprocal of the radius of the disc in centimeters. This method of annealing is exceedingly convenient for long geometrical figures, inasmuch as it requires only a very narrow cylindrical zone of constant temperature.* It is therefore applicable at all temperatures, and almost invaluable for high temperature work (500° to 1000°) where sharp distinctions of time are unnecessary and zones of definite constant temperature are not easily produced. In this way we obtained six *pairs* of hydro-electric couples, each of which consisted of glass-hard steel and the same steel annealed at one of the temperatures specified. Our first results were investigated with a zero method. They showed clearly that annealed steel is hydro-electrically positive with reference to hard steel, and that electromotive force increases with difference of temper. But in view of the large polarization discrepancies incident to these measurements, the electrometer is preferable to the zero instrument.

The following data were obtained with Mascart's apparatus adjusted to indicate 0·001 volt, accurately. The electrodes of the steel couples were immersed in a concentrated solution of zinc sulphate (pure), contained in a U-tube, the two limbs of the tube receiving the two steel wires. We kept them scrupulously bright by repeated scouring with sand paper. In the tables we give the electromotive forces e of the divers couples of hard and tempered steel, as well as the probable mean error of each. The means of the two values of e for each temperature of annealing are given in the second horizontal row and fairly exhibit the hydro-electric effect of temper in question.

The following data are the mean results of four series of measurements of five observations per series. The rods were scoured before beginning the first and the third of these series.

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* $2\pi \times \pi (0{\cdot}3) \overline{\text{cm}}^3$, or even a narrower cylindrical figure being sufficient. We have in view a similar method of quenching by which long continuous steel wires are drawn rapidly through a zone of high temperature into water.

Annealed at 20°. (Glass-hard.)		Annealed at 100°. (Steam.)		Annealed at 190°. (Aniline.)	
No. 9.	No. 10.	No. 1.	No. 2.	No. 3.	No. 4.
$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$
±4	±13	+12±4	−2±5	+19±3	+20±1
±0·009		+0·005		+0·020	

Annealed at 360°. (Mercury.)		Annealed at 450°. (Sulphur.)		Annealed at 1000°.	
No. 5.	No. 6.	No. 7.	No. 8.	No. 11.	No. 12.
$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$
+36±3	+34±3	+35±3	+40±3	+49±4	+54±4
+0·035		+0·037		+0·052	

The following data are the mean results of four series of five observations per series. Rods scoured before each series.

Annealed at 20°.		Annealed at 100°.		Annealed at 190°.	
No. 9.	No. 10.	No. 1.	No. 2.	No. 3.	No. 4.
$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$
±5	±2	+8±3	+7±1	+20±3	+24±2
±0·003		+0·007		+0·022	

Annealed at 360°.		Annealed at 450°.		Annealed at 1000°.	
No. 5.	No. 6.	No. 7.	No. 8.	No. 11.	No. 12.
$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$
+34±5	+27±1	+35±2	+43±2	+51±2	+65±5
+0·030		+0·039		+0·058	

The following data, finally, are the mean results of two series of three observations per series. Rods scoured before each series.

Annealed at 20°.		Annealed at 100°.		Annealed at 190°.	
No. 9.	No. 10.	No. 1.	No. 2.	No. 3.	No. 4.
$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$
±2	±4	+6±2	+6±1	+16±3	+25±1
±0·003		+0·006		+0·021	

Annealed at 360°.		Annealed at 450°.		Annealed at 1000°.	
No. 5.	No. 6.	No. 7.	No. 8.	No. 11.	No. 12.
$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$	$e\times 10^3$
+36±2	+34±1	+37±2	+39±2	+59±6	+65±8
+0·035		+0·038		+0·062	

The electromotive forces here encountered are small. It is necessary to take extreme precautions against all sources of error; otherwise mere discrepancies of polarization will exceed the largest values of electromotive force (e) found. If the parts of the liquid in which the steel wires are immersed differ at all in composition, we may look for a difference of potential at the surface of separation of those parts. The number of such surfaces in a solution (of solid, liquid or gas) may be indefinite. Hence it appeared desirable to repeat the above experiments with distilled water in place of zinc sulphate; to exchange the limbs of the U-tube twice for each series of measurements (commutation); to submerge equal surfaces of steel electrode in all cases. The results follow:

Annealed at 20°.		Annealed at 100°.		Annealed at 190°.	
No. 9.	No. 10.	No. 1.	No. 2.	No. 3.	No. 4.
$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$
±18	±28	+12±5	+28±9	+33±7	+20±8
±0·023		+0·020		+0·027	

Annealed at 360°.		Annealed at 450°.		Annealed at 1000°.	
No. 5.	No. 6.	No. 7.	No. 8.	No. 11.	No. 12.
$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$	$e \times 10^3$
+93±11	+85±6	+128±15	+82±9	+166±5	+205±3
+0·089		+0·105		+0·185	

A few supplementary data are given in the next table, where Nos. I and II are (+) iron / steel (−) couples, both metals softened at red heat; No. III a couple of two nominally identical iron wires; Nos. IV and V, couples consisting of steel in the commercial drawn state (+), and the same steel softened at red heat (−). The couples are immersed in distilled water. The extreme positive character of the commercial wires is in accord with the data for carburation, p. 277.

	I.	II.	III.	IV.	V.
$e \times 10^3 =$	+26±3	+63±2	±20	−69±5	−65±2
Mean $e \times 10^3 =$	+45		±20	−67	

The general results of these measurements are in accordance; the variations of potential, when taken as a whole, regular and decided. They show that *as hardness increases the hydroelectric position of steel moves continually in an electronegative direction.* The electromotive forces encountered are larger for the electrolyte distilled water than for zinc sulphate. The total range of variation in the former case (water) may exceed 0·25 volt. For zinc sulphate it scarcely reaches the one-third of this amount and decreases as the time of immersion increases. After submersion, moreover, the original electromotive force is not fully restored even by rubbing the electrodes.* When steel is immersed in water the effect of repeated scouring seemed to be an increase of electromotive force. These and similar annoyances which make the study of polarization phenomena so unsatisfactory are too well known to need further comment here.

If we avail ourselves of the observations made above on the rate of solution of tempered steel, we may infer, consistently with all the facts adduced, that inasmuch as the tempered electrode is covered with hydrogen at a greater rate than the hard

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* After long exposure of the wires to air the original force again appears.

electrode,* the former must be positive with respect to the other; that the phenomena in hand are mere effects of polarization. In other words, it is permissible to assume that the continuous variation of the mechanical texture of steel produced by annealing is the cause of corresponding variations of the rate of deposition of hydrogen on the submerged metal; that the electromotive forces observed are expressions of this hydrogen polarization, and bear no immediate relation to the electrochemical character of the steel electrode at all.

On the other hand, the dependence of the hydro-electric position† of steel, *caeteris paribus*, on the amount of free carbon contained is sufficiently obvious to conflict with this view. It is expedient to insert here a tabular comparison of the data under consideration. In the table, c denotes the number of grams of free carbon per gram of steel; e and e' the differences of potential between steel tempered and steel hard when plunged in zinc sulphate and in water respectively. Δ is the density, s the specific resistance, a the resistance-temperature coefficient, h the thermo-electric hardness of wires of the same kind of steel (Stubs' best). a and h are obtained by calculation.

Diameter $2\rho=0{\cdot}081^{\rm cm}$.

Annealed from hard at	c	e	e'	Δ	s	a	h
20°, ∞	0·0001	0·000	0·000	7·6547	43·9	0·0017	18·1
100°, $1^{\rm h}$	----	----	----	7·6666	39·3	18	16·2
100°, $13^{\rm h}$	0·0005	0·006	0·020	7 6745	35·5	20	14·6
190°, $1^{\rm h}$	----	----	----	7·6841	30·8	23	12·7
190°, $5^{\rm h}$	0·0007	0·020	0·027	7·6828	27·1	27	11·2
350°, --	0·0017	0·033	0·089	7·6806	20·7	33	8·5
450°, $1^{\rm h}$	0·0009	0·038	0 105	7·7190	18·4	36	7·6
530°	----	----	----	7·7227	18·2	36	7·5
690°	----	----	----	7·7272	17·2	38	7·1
810°	----	----	----	7·7586	17·6	37	(7·3)
1000°	0·0040	0·057	0·185	7·7705	18·6	37	(7·7)
Commercial.	0·0053	----	0·252	7·7268	16·3	0·0039	6·7

When steel of a given kind is operated upon and total carbon therefore a fixed quantity, the variable c affords a comparatively convenient means for detecting the presence and amount of chemical change; but it is highly probable that a clearer insight into the nature of the decomposition of carbide produced by annealing hard steel would be obtainable from a study of the character and quantity of the hydrocarbons (gaseous, liquid) volatilized during solution. They accumulate in copious

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* Hydrogen accumulates visibly on the + electrode when immersed in zinc sulphate.

† Curiously enough the observed points c and e' lie nearly on a right line.

amount long before the precipitation of carbon is perceptible or even when no appreciable precipitation occurs. If we regard c and e and e' correlated, then we have in hand an example of an exceedingly remarkable decomposition, which may be regarded incipient in hard steel even at ordinary temperatures, which is a certainly perceptible occurrence after annealing at only 100°, and which becomes more and more definitely marked and distinct as the temperature and the time of annealing increase. The anomalous character of this species of decomposition when occurring in a *rigid* solid we have already fully pointed out.* To obtain further information it is necessary to investigate the relations of the variable c minutely. Finally, the critical difference between the thermo-electric and the hydro-electric behavior of steel is well shown by constructing h as a function of e'.

We are not at present prepared to discuss the general question further. Such discussion, to be satisfactory, presupposes a knowledge of the relations of the variables in the table for steel identical in kind and temper, exposed to the action of temperature under identical conditions—a desideratum which the tabulated treatment and the results do not, as yet, fully supply. We therefore merely remark that if we had come upon the hydro-electric results earlier, we should not have considered it safe to dwell upon the exclusive importance of the strain-effect during the first phase of the phenomena of annealing. With this assertion we do not wish to imply that the views of the preceding papers are to be modified.

Washington—Prague, June, 1886.

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* "On endeavoring to use the chemical hypothesis of tempering to account for the phenomena of annealing, we at once encounter serious difficulties. On the basis of this theory there must exist a fixed ratio of combined to uncombined carbon for each temperature of the annealing bath. Moreover, for a given temperature this ratio must be approached gradually (asymptotically) as time of exposure is prolonged indefinitely; for different temperatures it must decrease as temperature increases indefinitely, until finally a minimum value wholly independent of temperature is asymptotically reached. The minimum of the ratio of combined to uncombined carbon need not, of course, be zero. The last phase of this decomposition is in many respects similar to the phenomena of dissociation. The resemblance can, however, only be apparent, since continuous dissociation has not been observed except in the case of gases. At least, to our knowledge, there are no chemical examples in which solids are found to dissociate in accordance with the laws to which gases, in virtue of their physical state, must conform, and for this reason the explanation of the phenomena of annealing given by the chemical theory is remote and forced, and to be discarded. We gain no more by adopting Matthiessen's hypothesis, which considers all iron-carburets as solidified more or less thorough solutions of carbon in iron."—*Bull. U. S. G. S.*, No. 14, p. 94, 1885.

ART. XXXIII.—*On the Crystalline Structure of Iron Meteorites;*[*] by OLIVER WHIPPLE HUNTINGTON.

THE general octahedral structure of iron meteorites was observed soon after the attention of mineralogists had been directed to this remarkable class of bodies.

In the year 1808, von Widmanstätten[†] of Vienna observed the crystalline figures brought out on a polished section of the Agram iron by tempering or etching, which have since been known by his name. That these figures might be due to an octahedral structure is said to have been remarked by Berzelius,[‡] and as early as 1816 was inferred by Sömmering from definite measurements of angles between the lines of the figures. In the same year, Wollaston remarked that the iron from Bemdego (Bahia) had an octahedral cleavage,[§] and later, in 1839, still more striking evidences of octahedral structure were described by C. U. Shepard in his paper on the Asheville meteoric iron.[‖] Furthermore, in 1861, von Reichenbach studied with great detail all the minute features which are presented by the Widmanstättian figures, and published his results in a series of papers in Poggendorff's Annalen entitled "Ueber das innere Gefüge der näheren Bestandtheile des Meteoreisens."[¶] He first made the distinction between the different conditions of nickeliferous iron forming the material of the crystalline plates of which the Widmanstättian figures are sections, and introduced into the descriptions of these bodies the now familiar terms of Balkeneisen, Bandeisen and Fülleisen, which he also designated respectively as Kamacite, Tænite and Plessite.

In the year 1864, Gustav Rose, in his "Beschreibung und Eintheilung der Meteoriten," distinctly pointed out the octahedral arrangement of the plates which form the Widmanstättian figures, and compared the structure of meteoric iron with the lamellar structure of many leucite and magnetite crystals, regarding the crystalline mass as consisting of scales or plates of iron separated by laminæ of the iron and nickel alloy which Reichenbach called Tænite.

In 1848, Neumann,[**] in studying the structure of the Hauptmannsdorf (Braunau) iron, concluded that the fine linear markings which appear on etching the faces of the remarkable cubic forms obtained by fracture were essentially distinct from the

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[*] From the Proceedings of the American Academy of Arts and Sciences, May 12, 1886.

[†] Schweigger's Journ., lii, 172.

[‡] This Journal, III, vi, 18.

[§] Phil. Trans., 1816, p. 281.

[‖] Journal, I, xxxvi, 82.

[¶] Poggendorff's Annalen, Bd. cxiv.

[**] Naturwiss. Abhandlung ber. v. Haidinger, vol. iii, pt. ii, p. 45.

Widmanstättian figures, and such lines have since been known as Neumann lines, and have been supposed to indicate a cubic structure, just as the Widmanstättian figures had been supposed to mark solely an octahedral structure.

On this basis, iron meteorites are now generally classified under two chief groups, as the octahedral and the cubic. This distinction, originally made by Gustav Rose, has been brought into prominence by Dr. Brezina in his recent catalogue of the collection of meteorites at the Vienna Museum, and in this catalogue both the cubic and octahedral meteorites have been further subdivided by him into numerous sub-groups, marked solely by the width and other features of the figures or lines.

That such a classification cannot be natural or fundamental is shown by the disagreement of equally competent observers in regard to the character of the figures or lines in special cases, and also by the circumstance that the figures may appear very differently on separate masses of the same fall, and even on different parts of the same section. For example, the iron from Ovifak, Greenland, in regard to whose meteoric origin there has been so much question, is described both by Dr. J. Lawrence Smith and Daubrée as yielding distinct well-marked Widmanstättian figures, while Dr. Brezina insists that it shows absolutely none. In like manner, the well-known iron of Santa Catarina is described by Daubrée, Damour and others, as exhibiting distinct Widmanstättian figures, while Dr. Brezina not only asserts that no figures could be developed on any specimens which have come under his notice, but even calls in question the discrimination of the eminent mineralogists just quoted. Again, Dr. Brezina, in criticising some observations of Dr. Walter Flight of the British Museum, includes the iron of Babb's Mill among those which exhibit no Widmanstättian figures; but the specimens, of unquestionable authenticity, in the collection of Harvard College show well-marked figures. Furthermore, an etched surface on a mass of Nelson County iron weighing 6,800 grams, and measuring 13 inches in its longest dimension, presents perfectly distinct figures near the centre of the section, which grow indistinct near the edges, and entirely fade out at one end. On the other hand, the iron of LaCaille, classed by Dr. Flight with the irons giving no figures, shows, as Dr. Brezina truly remarks, very well developed figures when the sections are made in most directions; but we have etched surfaces of this meteorite which over several square inches of area show no figures whatever.

In view of such differences of observation and opinion as the above examples indicate, it seemed desirable to make a still further study of the crystalline structure of iron meteorites, and Professor Cooke placed at my disposal for this purpose the very large collection of Harvard College, which, since the acquisition of the collection of the late Dr. J. Lawrence Smith, has representatives of all the characteristic meteorites of this class. The writer has been familiar with this collection since it was acquired by the college, and, in examining the specimens from time to time, he has been struck by the indications of crystalline form which many of them present. These appear like rough octahedrons, and their irregular faces present the most striking similarity to cleavage planes, although in some cases the surfaces are covered and the edges rounded by a fused crust. On further examination, it appeared evident that the surfaces in question must be true crystalline faces, for not only were these faces parallel to planes of fracture as indicated by rifts through the mass, but they also stood in a definite relation to the Widmanstättian figures. Moreover, rifts of fracture were common when no external crystalline form could be made out, and hence came the idea of using the cleavage faces as planes of reference in studying the crystalline structure of the iron meteorites; and the plan was formed to grind, polish and etch surfaces either parallel to the cleavage planes or in a known position towards them, with the hope that it might thus be possible to determine with certainty the relations of the crystalline plates whose cross-sections form the Widmanstättian figures. This was in general the plan of the investigation whose results are here given.

The most striking example of such a rude cleavage form as has been described is a mass of the Franklin County (Kentucky) iron weighing 7,260 grams, which shows all the planes of an octahedron, inclined to each other at the regular octahedral angle (109° 28′) as nearly as the uneven surfaces of the faces would admit of measurement with an application goniometer. This large, unique, isolated octahedron, of massive iron, measures seven inches in its longest dimension, and one of the triangular faces distinctly outlined measures over four inches on each edge. Another face, still more distinctly marked, measures three inches on each edge. At various points there are triangular depressions or reliefs conforming to the general outline, features which are so characteristic of large crystals; and there are also numerous rifts parallel to the octahedral faces. A large part of the surface is covered with a crust, and, on the basis of the usual interpretation of meteoric phenomena, it is obvious that this crystal is the fragment of an iron meteorite broken up after entering the atmosphere, but while still moving rapidly enough to produce a melted crust over the surface of fracture.

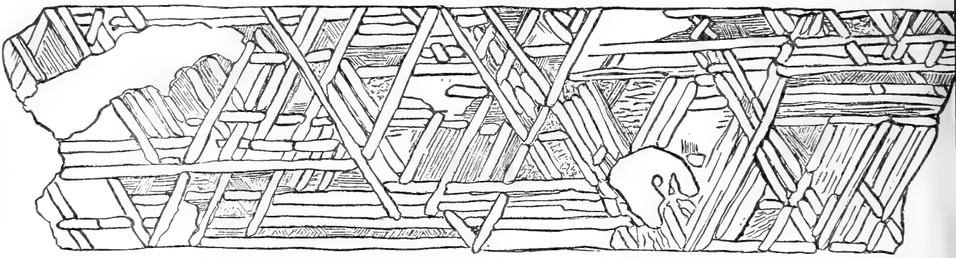
Another example in the Harvard collection of external octahedral form is a specimen of the Carthage (Smith Co.) iron.

This specimen shows six faces of a rough octahedron, one of the faces having an area of seven square inches. One half of this octahedron has been partially torn apart into numerous smaller crystals, some of them an inch or more in diameter; but though the crevasses between the individuals are in some places nearly a quarter of an inch in breadth, yet they are bound firmly together by a network of plates, which in some parts raggedly jut out from the octahedral faces. The general appearance of the exterior of the specimen reminds one somewhat of a rough mass of galena crystals, only of octahedral form. The rough crystal is evidently the result of fracture, probably caused during the passage of the mass through the air, and the octahedral faces are cleavage planes, if the term cleavage may be applied to such fractures, which cannot be reproduced by splitting in the ordinary way on account of the malleability of the mass. The specimen further exhibits a fused crust over the octahedral faces, which must have formed after the partial breaking up of the large mass, giving a rounded appearance to the edges. On a polished surface, cut nearly parallel to the largest octahedral face, the figures produced by etching appear very strikingly. They are perfectly distinct and regular, being typical Widmanstättian figures; but when they come to the cracked portion of the iron, they appear as separate plates, some having been broken by the rupture, others separated, while the greater number appear bent and strained, but still coherent and binding the mass firmly together. The whole appearance on the etched surface gives at once the idea of a forcible explosion, and yet all the cracks, even the most ragged, follow directions parallel to the octahedral faces.

A second specimen of the same iron, measuring twelve and a half inches in its longest dimension, and weighing 9,980 grams, is a very remarkable mass of cleavage octahedrons, loosely packed together and piled on top of each other, not unlike crystals of alum, and almost as sharply defined. The largest octahedral face measures five inches in diameter, but is made up of numerous smaller crystals, in some places jutting out and in others receding, forming numerous triangular projections and depressions.

Another striking octahedral mass is a fragment of the well-known De Kalb County meteorite. One specimen of this iron shows hollow octahedral faces, two inches in diameter, like hopper crystals, consisting of skeletons built up of a series of plates about half an inch wide and one-sixteenth of an inch thick. These plates, when cut transversely, constitute the Widmanstättian figures. When the section is cut at random, the figures may differ somewhat in character, and the plates appear to make various angles with each other; but when the etched surface is parallel to an octahedral face, the Widmanstättian figures all make equilateral triangles, their sides being parallel to the octahedral edges.

1.

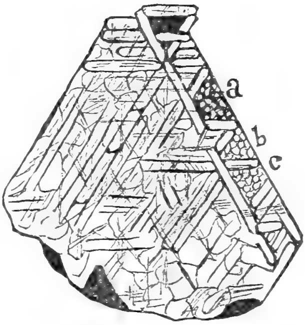


De Kalb County.

Such a section is shown in fig. 1, which is part of a surface cut parallel to an octahedral face of the De Kalb specimen just referred to. The figure is an exact sketch, representing the plates of their natural size. The most noticeable character in the figure is the system of broad bands which divide the mass into equilateral triangles. These are cross-sections of the crystal plates, which, in another part of the specimen, stand out so markedly in forming the hollow-faced octahedrons. These plates consist of the purer iron to which Reichenbach gave the name of Balkeneisen, or Kamacite, and they are separated from the groundmass by a thin layer of iron rich in nickel, called by Reichenbach Bandeisen or Tænite. This material is not readily acted upon by acid, and therefore appears on the etched surface as a bright silvery line along the edge of the kamacite plates. In some meteorites, as in the Cocke County and Sevier County, it occurs in sufficient mass to be easily separable from the plates in the form of a thin elastic foil, while in others it almost wholly disappears. The thin plates of "bandeisen" resist the action of oxidizing agents, as they resist the action of dilute acid, so that, when the surface of the meteorite becomes disintegrated by air and moisture, these plates not unfrequently become loose, and are easily separated. Dr. Lawrence Smith analyzed the material of some plates thus obtained from the Sevier County meteorite, and found in them 27 per cent of nickel. The groundmass consists of what Reichenbach calls Fülleisen, or Plessite. In the present case, the latter is filled with very thin plates, or "combs," in general following the octahedral directions and appearing to be a subsequent crystallization, as if the larger plates had first shot through the mass when in a liquid state, and then, as the interior portions solidified, these also crystallized more or less perfectly, but forming smaller and smaller plates.

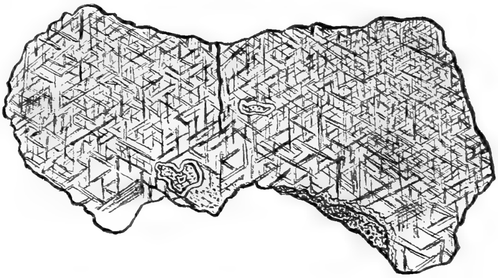
Figure 2 shows, double the natural size, one face of a very perfect octahedron broken out from the Putnam County meteorite. This iron appears by oxidation of the surface to break up into octahedrons and acute rhombic prisms. The octahedron represented in fig. 2 was so loose in its structure that it was necessary first to mount it in pitch before grinding the face in order to prevent the plates from splitting off. Here the character is much the same as in the previous one, except that the plates are smaller, and at the points *a*, *b* and *c* the iron is perfectly granular, showing no signs of crystallization. Moreover, the groundmass, instead of containing the combs above mentioned, has been broken up by a series of irregular cracks into coarse grains, very much like a mass of crackled glass. Another meteorite which most beautifully illustrates the octahedral arrangement is the Tazewell (Claiborne Co.) iron, fig. 3. Here the figures brought out by etching are very sharply defined, but are so small that, in some parts of the field, it seems as if there were almost no limit to the fine bands as seen with an ordinary pocket lens. The bands, though small, exhibit all the features of the coarser Widmanstättian figures. On the exterior of the mass, small octahedral planes are distinctly visible, and a crack, shown

2.



Putnam Co., Georgia.

3.



Tazewell, Claiborne County.*

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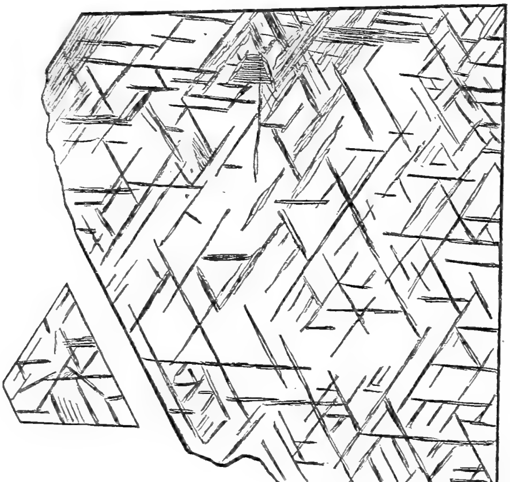
* The illustrations of this paper were made by the Lewis Engraving Company, and although in the details they are faithful reproductions of the drawings from which they were taken, yet the lines are all too heavy, and give the idea of a much coarser structure than the meteorites actually present. This is especially true of the above cut.

by the heavy line in the figure, following the octahedral cleavage, nearly separates the mass into two portions.

So far, the observations on octahedral irons do not differ materially from what has been described in the papers already referred to. The Widmanstättian figures are manifestly the evidence of a very perfect crystallization, chiefly in the octahedral form; and these octahedral plates frequently may be readily separated, the successive depositions of the plates producing a more or less jointed structure, similar to that well known in cap-quartz. But this jointing must be clearly distinguished from the octahedral cleavage or fracture above referred to, which, as already stated, often passes directly through the plates. Moreover, the perfection of the octahedral cleavage does not depend upon the size and character of the Widmanstättian plates, many of the irons which show the best figures affording no evidence of octahedral cleavage, while some of the most compact break readily into octahedrons.

4.



Butler, Bates County.

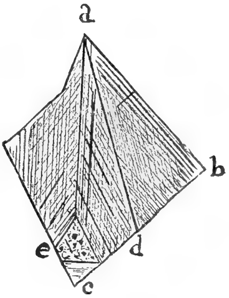
An example of the latter is shown in fig. 4 from the Butler (Bates Co.) iron, where the larger surface, drawn of its original size, shows that the Widmanstättian figures are very fine, and not in broad, distinct plates, while some of them are even microscopic; and yet from this iron was obtained a far more perfect octahedron than from any of those with a coarser structure. The smaller sketch shows one face of such an octahedron, twice the original size. This octahedron showed seven perfectly even regular octahedral faces, the eighth face having been hollowed out where it formed part of the crust of the meteorite.

All the faces were polished and etched so that the plates might be followed through their entire extent. On examination, it appeared that the majority of the plates, including even the finest microscopic markings, followed the direction of the octahedral faces. But there will be noticed in the sketch of the octahedral face, that, in addition to the usual directions, there appear certain plates which bisect the facial angle of the octahedron. These plates, when followed over an edge on to an adjacent face, were seen to be parallel to an octahedral edge, showing that they must be dodecahedral instead of octahedral.

Thus it at once appeared that the Widmanstättian figures could not be solely characteristic of octahedral structure. Furthermore, the Butler meteorite seemed to stand between well-marked Widmanstättian figures and the finer lines discovered by Neumann and shown by him to be parallel to cube edges. Some of the Butler figures are coarse enough to be classed unquestionably as Widmanstättian, that is, they show the three varieties of iron distinguished by Reichenbach, which he calls the Trias; while others of the figures are almost microscopic markings, in which distinct plates of kamacite and plessite cannot be made out even under the microscope. Between these two extremes there is every gradation. The Butler meteorite has always been classed among the octahedral irons. We come next to the Coahuila, which has been classed with the so-called cubic irons.

A large section of this iron, on being etched, showed innumerable fine lines, seeming at first sight as irregular as the markings on a chopping-block. When this section was examined under the microscope, it showed all the characters of the Butler figures, only a degree finer. On studying the directions of the lines, they appeared to make every possible angle with each other, but with a prevalence of right angles. The meteorite is very compact, with usually no external crystalline form, but it was found that on one specimen, by quick blows of the hammer, cleavage masses could be broken away. One of these cleavage masses is shown, of twice its original size, in fig. 5. It has the well-known form of the cube twin, described by Tschermak* as typical of the Hauptmannsdorf iron, but with this difference, that the cube in this case is modified by the octahedron. On polishing and etching the crystal faces, the lines appeared so fine as to be for the most part indistinguishable by the naked eye, but

5.



Coahuila, Mex.

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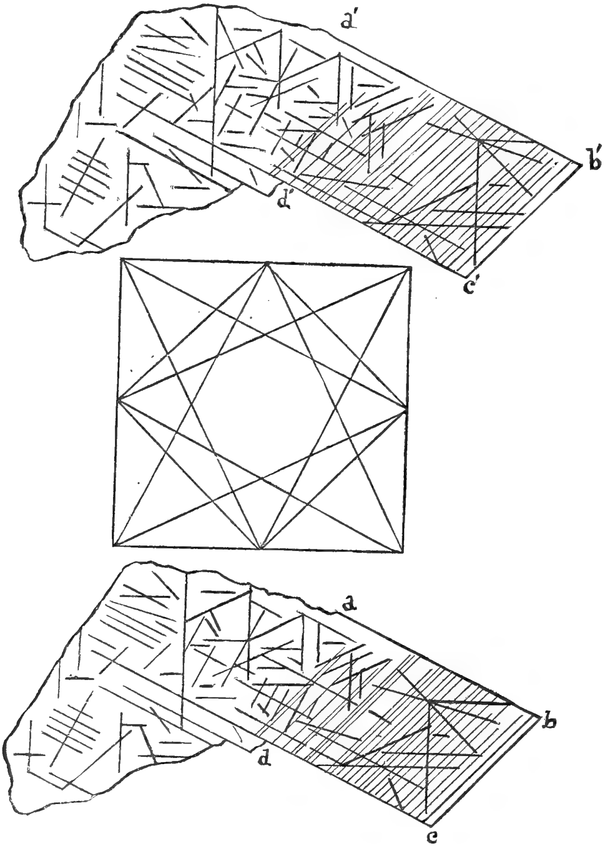
* Akademie der Wissenschaften Wien, lxx, 449.

under the microscope showing most beautiful markings, all parallel either to the cube edges or to those of the octahedron. Most of the lines were so fine as to appear like the finest striations, while a few, on the other hand, were coarse enough to be recognized by a pocket lens as consisting of plates with all the characters of the finer Widmanstättian figures.

6.



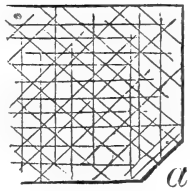
Coahuila, Mexico.

In actual contact with the crystal just described appeared an acute rhombic prism with an angle of about 120°. This prism, shown of twice its size in fig. 6, could only be separated by the hammer over the area *a b c d*, and the rest of the face had to be continued by cutting through a very compact part of the specimen. *a b*, *b c* and *c d* are the natural crystal edges, and the three faces of the prism not shown in the figure were chiefly characterized by the system of fine lines seen here parallel to *c b*. The lower of the two drawings was made from the original specimen, without a knowledge of what the angles were; but on examination it was found that the lines, and prism faces as well, could all be referred to a cube with twin members on all the trigonal axes.

The face of such a twin is represented by the diagram between the two figures of the crystal, and the upper figure was actually drawn from the cube diagram by means of a parallel ruler, and it will at once be seen from the close coincidence of the two figures that the upper one must be correct, the lower one only varying within the limit of error of a mechanical drawing.

On examining the Hauptmannsdorf iron, which has long been known to break with a cubic fracture, a cube face under the microscope appeared, as shown in fig. 7, some of the lines being parallel to the cube edges and others forming diagonals of the cube face. These diagonals might be octahedral lines or dodecahedral lines, or they might be lines of cleavage parallel to the face of the other individual of a twin, and as the face shown in section replacing the cube angle at *a* was the face of a twin cube, the lines parallel to that edge would probably be due to the same plane; and this was proved to be the case, as on an adjacent face the same lines followed the direction of twinning. These lines of twinning are not represented in fig. 7, to prevent confusion.

7.

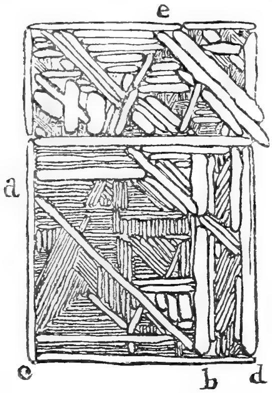


Hauptmannsdorf (Braunau.)

Thus the Hauptmannsdorf iron appears to be purely cubic in structure, while the Tazewell appears to be purely octahedral. However, as the octahedron was observed in the Coahuila iron, and the dodecahedron appeared in the Butler iron, it became a question whether the cube and dodecahedron could not be found in the typical octahedral irons. A very large number of irons were studied with this end in view, but nothing could be determined with specimens where only one face could be examined. It was necessary to have two known crystal faces, and to be able to follow the plates over an edge. For on a cube face the octahedral plates give rectangular intersections, while on an octahedral face the cube plates would give intersections parallel to the octahedral edges.

Figure 8 shows of original size a section of the well-known La Caille meteorite, cut parallel to an assumed cube face, the direction being determined by external well-developed octahedral faces. Here the rectangular intersections *a c* and *c d* result from octahedral plates intersecting the cube face, but there are also diagonals of this rectangle. The plate *a b* and those parallel to it make an angle of 45° with *c d*, and when traced on to an adjacent face, cut at right angles to the one in the figure, they follow the direction of a dodecahedral plane, and on the under side of the specimen there appeared a large natural face, an inch in diameter, exactly parallel to this same plate. This face measured, as shown by an application goniometer, 145°, with an adjacent octahedral face, showing that it was the face of a dodecahedron truncating the octahedral edge; and when etched neither of these faces showed any Widmanstättian figures, but only a mottled appearance, as is usually the case with a surface consisting of a single plate. The other oblique lines in the direction *c e* make an angle of 66° 19′ with *c d* and are plates of the twin octahedron corresponding to the twin cube before mentioned.

8.

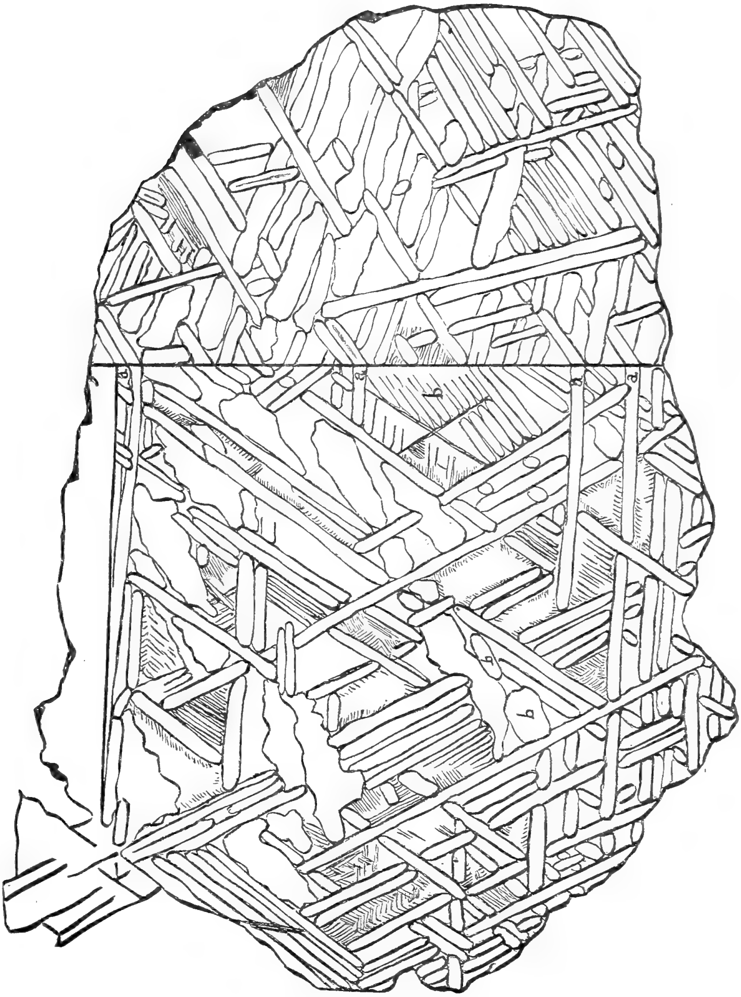


La Caille.

Figure 9 shows, of original size, two sections of the Robertson County iron. The left-hand half of the figure is parallel to the octahedral face, while the right-hand half is a face at right angles to the first, and in the upper left-hand corner is shown an octahedral cleavage. Here most of the plates are octahedral, and are at once recognized, but the plates marked *b* and also the irregular cloudy-looking masses bisect the octahedral angle, and these follow a dodecahedral direction while the plates marked *a* on the octahedral face are parallel to a lateral edge, and, on following the plates on to the face at right angles to the first, it will be seen that they continue to be parallel to the lateral edge. Hence they cannot be octahedral plates, and, since they are parallel to a principal section of the octahedron, they must be cubic. In order to see whether the Robertson County iron was an unusual case of cubic plates, other well-marked Widmanstättian irons were examined, and in the same way the cube was found, together with the dodecahedron, in the De Kalb iron before mentioned, and also in the Obenkirchen or Oldenburg iron. Undoubtedly, many other examples could be found, provided the proper faces could be distinguished and etched.

Thus it is evident that, in the first place, there is a regular unbroken gradation between the coarsest Widmanstättian figures and the finest Neumann lines; so that, beginning with the Nelson Co. iron, we can arrange a series consisting of the irons of Wichita Co., Glorieta, Red River, Robertson Co., Dickson Co., Oldham Co., Jewell Hill, Obernkirchen, Tazewell, Butler, Walker Co., Coahuila, and Hauptmannsdorf, presenting regular gradations in which there is no gap at which a definite line of demarcation can be drawn.

9.



Robertson County.

Moreover, there is no difference in crystalline form even so slight as that between the three fundamental forms of the isometric system. For, as has been shown, the coarsest Widmanstättian figures as well as the finest Neumann lines are intersections of planes of crystalline structure, which may be parallel to faces of the octahedron, the dodecahedron, or the cube.

Of course it is not maintained that there is not a marked distinction between characteristic Widmanstättian figures showing all the features of the three kinds of iron, and typical Neumann lines as exhibited by the Hauptmannsdorf meteorite, but only that both are an outgrowth as it were of the same type of crystallization.

The Germans strongly insist on the divisions of the trias of Reichenbach, and describe the features of kamacite, tænite and plessite as if they were essentially different substances, instead of merely different conditions of a nickeliferous iron; and the only evidence we have that there is any material difference of composition is based on an analysis cited by Reichenbach* of the so-called tænite plates, which he had mechanically separated from the Cosby Creek iron, and which were found to contain 13·8 per cent. of nickel, while the mass as a whole only contained 9·8; and, on this ground, it is assumed that kamacite consists of a purer iron. As stated above, Dr. Lawrence Smith found in plates obtained from the Sevier County iron, which is closely allied, if not identical, with the Cosby Creek, 27 per cent of nickel. This supposition would harmonize with our idea of the manner in which crystallization takes place. For though a substance in crystallizing may include foreign substances, still crystallization is a purifying process. Hence, as the molten metal cooled, there would be a tendency for the pure iron to crystallize first, thus forcing back, as it were, a less pure material, which would solidify subsequently; and the natural alternation of such stages, during a very slow process of crystallization, would result in a succession of plates of comparatively pure metal interlaminated with a richer nickel-iron alloy.

This theory is strongly supported by the structure of the Pallasites, where the iron occurs surrounding masses of olivine. Here, as Reichenbach has so beautifully shown,† the silicate grains are first surrounded by a deposit of kamacite, and the trias does not appear till this layer of the purer iron has been deposited.

Moreover, Tschermak has shown,‡ in regard to artificial irons, that pure iron tends toward a cubic crystallization with markings similar to the Hauptmannsdorf meteorite, while impure iron, like cast-iron, frequently shows imperfect octahedrons and a scaly structure, not unlike that of many meteorites, and this becomes very striking in the so-called spiegeleisen.

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* Poggendorff's Annalen, cxiv, 258. † Ibid., p. 99.

‡ Akademie der Wissenschaften, Wien, II, lxx, 447.

We know very little as yet of the causes which determine the crystallization of substances with an isometric structure in one or another of the three fundamental forms, but we do know that constantly the presence of some foreign material in the crystallizing menstruum produces a marked influence on the result. Thus, common salt, which usually crystallizes in cubes, crystallizes in octahedrons from solutions containing urea. Then again, galena may crystallize under unknown conditions in all three of the fundamental forms. Indeed, the crystallization of galena presents a striking analogy to that of iron as it appears in meteorites. It was shown many years ago, by Professor Cooke,* that galena, like the iron, may be cleaved parallel to faces of all three fundamental forms. Usually the cubic cleavage is the most pronounced; but in the remarkable variety from Lebanon County, Pennsylvania, the octahedral cleavage is the more eminent, although both the cubic and dodecahedral can also be easily obtained.

In connection with this, it is interesting to note that, on polishing and etching octahedral, dodecahedral, and cubic faces on crystals of galena, lines were developed precisely similar in character and position to the Neumann lines. Now it is to be remarked that on the cube faces of the Hauptmannsdorf iron, which Reichenbach regards as consisting of kamacite only,—that is, the purest form of iron,—we have a prevailing cubic structure, as indicated by the so-called Neumann lines. But in proportion as the iron in the process of crystallization has excluded foreign material, as shown by inclusions such as graphite, sulphide of iron (troilite), phosphide of iron (schreibersite) and the like, the octahedral form prevails.

It is further to be noticed in this connection, that on the sections of kamacite plates in characteristic octahedral irons fine lines appear called "Schraffirung" by the Germans, which are evidently identical with the Neumann lines, and these follow the direction of the prevailing crystalline form. Hence, on this view, the coarser structure which gives rise to the Widmanstättian figures with the well-marked trias of Reichenbach is connected with the exclusion of incompatible material in the process of crystallization, while the more uniform structure of the so-called cubic meteorites, marked by the Neumann lines, depends on the circumstance that the material was susceptible of crystallization as a whole. It is by no means necessary that, to fulfill this condition, the material should be pure iron. It may be an alloy capable of crystallizing in mass, as is the case with many crystalline alloys.

We conclude, then, that the crystalline structure of the coarsest octahedral irons is not more definite than that of the

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* This Journal, II, vol. xxxv, p. 127.

cubic irons; but in the first case the process of crystallization determines the elimination of the various materials which form the Widmanstättian plates, while in the second case no such elimination takes place, and between these extremes there is every gradation. The element of time may also be an important, and perhaps the chief, condition in determining the result, for we should naturally expect that, during a very slow crystallization, foreign material would be more completely eliminated than during a process which was comparatively rapid. That the crystalline structure is equally definite in both cases, is shown by the fact that cleavage forms may be developed with equal readiness in either class of irons.

Though there are no very definite data in regard to the crystallization of nickeliferous alloys, yet it has been suggested that the presence of nickel in the meteoric iron might determine its crystallization. It has been thought that between certain limits in the per centage of nickel present octahedral structure might result, while with a different amount of nickel the crystallization would be cubic. With an idea of deciding this point if possible, the analyses of eighty meteoric irons, as given in various scientific journals, were tabulated according to their per cent of nickel, and at the same time the size and character of the figures produced by etching were noted. Unfortunately, these results appeared so discordant that no trustworthy conclusion could be drawn from them, for it was frequently the case that the composition of the same meteorite as given by equally competent analysis differed by several per cent. Thus the per centage of nickel in the Babb's Mill meteorite has been variously stated as 14·7, 17·1, 4·7 and 12·4, and yet this appears to be a perfectly homogeneous iron.

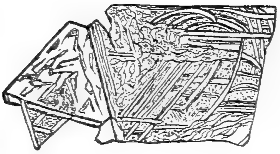
Dr. Flight of the British Museum has made the remark, that Widmanstättian figures seldom appear in irons containing more than nine per cent of nickel, and it appears to be true that most of the irons giving well-marked Widmanstättian figures contain from five to nine per cent of nickel, though they vary all the way from 3·12 to 17·37 per cent. On the other hand, the irons giving well-marked Neumann lines contain generally only five or six per cent of nickel, but the data at present are insufficient to afford any basis for generalization.

Moreover, it is by no means as yet established that the amount of nickel present is the cause which determines the difference of feature in the crystallization of meteoric irons, nor should we be led to infer that such would be the case from the behavior of alloys of metals so closely allied as nickel and iron. It is certainly quite as probable that the effect may be due to some other impurity,—for example, to the presence of phosphorus, which is known to produce such marked effects on the physical properties of iron. According to the analysis of Reichenbach already cited, the tænite plates of the Cosby Creek meteorite contain 0·295 per cent of phosphorus, while the mass only contains 0·089 per cent, and it is well known that schreibersite, which is a phosphuret of iron containing fourteen per cent of phosphorus, constantly appears on sections of meteoric iron, in lines along the bands of kamacite. But our knowledge of the amount of phosphorus in the different meteorites is even less complete than our knowledge of the per cent of nickel. We do not know, in regard to any of the impurities, either the average amount in any considerable portion of the meteoric mass, or to what extent the amount varies in different portions of the same mass. The most we know, in any case, is the composition of one or more fragments selected for analysis, and, as we have shown, even these data are so discordant as to be wholly untrustworthy. It is impossible to infer with certainty from the descriptions whether the disagreement arises from faulty methods of analysis, or from actual difference of composition in the fragments selected; and no satisfactory conclusions can be reached in regard to the influence of impurities on the crystalline structure, until an extended series of systematic analyses has been made of the iron meteorites, by processes which have been well considered, and the limits of whose accuracy have been carefully determined. In such a chemical investigation, regard should be paid to the probable variation in composition of different parts of the mass. This is a subject to which we hope to return at a future time.

The action of the process of crystallization in eliminating impurities produces effects with many minerals not unlike those of the Widmanstättian figures. Very striking exhibitions of such effects may be seen with the microscope in rock-sections containing crystals of leucite, nosean, nepheline and other minerals. Illustrations of these phenomena have been given in works on lithology, and it is only necessary to allude to them here, in order to make clear their analogy with the phenomena we are studying. But a far more striking illustration of this similarity is shown by a large specimen of fluorite in the Harvard collection, which has been cut through a mass of compacted crystals. The polished surface imitates very closely the features of the Widmanstättian figures. There are distinct bands, marked by difference of color instead of difference of luster, separated from the groundmass of the mineral by definite layers of less pure material. The bands are about the width of those in the Glorieta meteorite, and they all appear alike, bordered in every case by the same layers of impurities arranged in a definite order, and these bands, crossing at various angles, with a predominance of right angles, bear a most striking resemblance to the Widmanstättian figures. Such examples as these indicate clearly that the Widmanstättian figures are not a peculiar phenomenon, but that such an alternation of plates is often a characteristic of crystalline structure, when the process of crystallization is attended by the elimination of foreign material.

There is another feature of the Widmanstättian figures which often appears, and which is best explained by the assumption that the process of crystallization was extremely slow. Figure 10 shows two faces of a very perfect octahedron, drawn of original size, from the Cranberry Plains (Poplar Camp) iron. It will be seen by this sketch that the octahedral outline has been sharply formed; but while many of the Widmanstättian plates are parallel to this outline, there are others which are markedly curved. These curved plates must have originally formed through the liquid mass as true planes, like their neighbors, and have been bent in the subsequent solidifying of the remaining material. For, if they had been distorted by an exterior force, the regularity of the octahedron would have been at the same time destroyed.

10.



Cranberry Plains.

This phenomenon of curved plates has been made a basis of subdivision in the classification of iron meteorites. But it is evident from the figure that the bending is not a constant or essential character, as the plates are not all curved, but only appear so at particular parts of the mass, and some specimens show no trace of such a feature. In a word, such curved plates are simply accidents of the crystallization. Very similar bending is common in various minerals, as in gypsum, and very conspicuously in the beautiful crystals of stibnite which within the few last years have been brought from Japan.

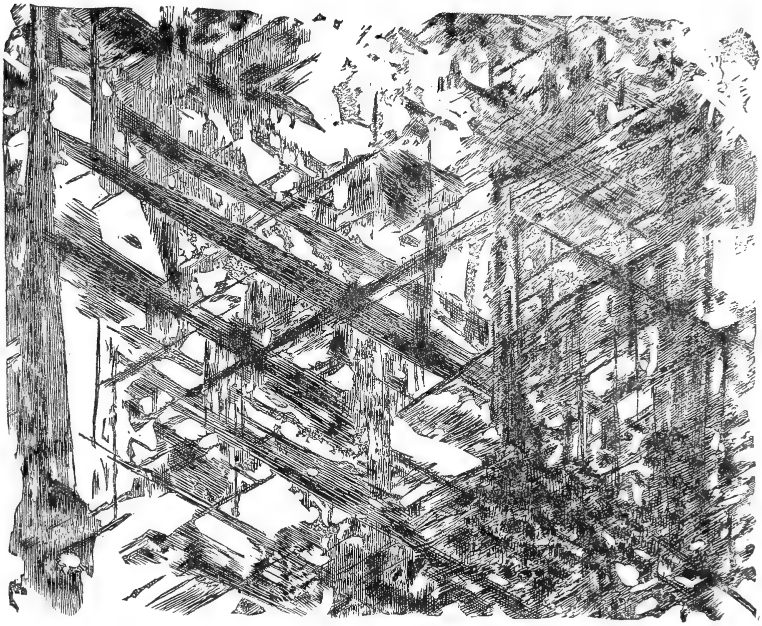
A similar remark might be made in regard to the swellings formed in the kamacite plates around inclusions of troilite, schreibersite, and the like, which have been so minutely described by Reichenbach, and named by him "Wülsteisen."* These again are accidents of crystallization, which have their counterpart in other crystals, and are most beautifully shown on the plates of mica from Chandler's Hollow, Delaware, where the depositions of magnetic oxide of iron on the planes of the crystalline growth of the mica produce effects which imitate in a most striking manner the Widmanstättian figures.

We give in fig. 11 as perfect a representation of one of these mica plates as could be obtained by the photographic process

* Poggendorff's Annalen, 1861, cxiv, 477.

used in illustrating this paper, and it will be seen that the resemblance is very close. The analogy here is far more than superficial, and shows, as we conceive, the mode of action by which the Widmanstättian figures were produced. This will be evident if it is borne in mind that the figures on the mica plate are also sections of planes of crystalline growth on which the particles of oxide of iron eliminated during the process were deposited. Of course, the mere resemblance in the outline of the two sets of figures is accidental, and arises from the circumstance that the planes of crystalline growth of muscovite mica are parallel to a rhombic prism of sixty and one hundred and twenty degree angles, the right section of such a prism being similar to the section of a regular octahedron parallel to one of its faces.

11.



Mica.—Chandler's Hollow, Delaware.

The conditions of the plessite which fills the cavities between the crystalline plates of iron meteorites also present features which are especially characteristic of the crystallization of alloys. Sometimes the space is packed with small crystalline plates parallel to those of the external form, the combs already mentioned, shown in fig. 1. Again the material is granular, as shown at *a*, *b* and *c*, fig. 2, or again divided into polygonal masses as shown in the same figure. Similar features in the alloys of zinc and antimony have been described by Professor Cooke,[*] and in the alloys of copper and zinc by Prof. F. H. Storer.[†] They correspond to that pasty condition so well known to plumbers and workers in alloys. We here refer only to the conditions of the plessite; but at times we also find the whole meteoric mass divided up by small cracks, and thus rendered so friable that it can readily be broken into coarse polygonal grains with a hammer. Such a disintegration must have been a mechanical one, affecting the whole mass subsequent to its solidification. It is similar to the well-known effects produced on iron by long-continued jarring, and may have been the result of the violent concussions which are known to be caused by the passage of the meteorite through the air. We have recently had the opportunity of examining a specimen of aluminium bronze sent to the Laboratory of Harvard College by Professor C. F. Mabery of Cleveland, Ohio, which most strikingly illustrates the effect here described. The bronze, consisting of 90 per cent copper and 10 per cent aluminium, had been cast into a bar and reheated for forging. When the heated bar was laid on an anvil and struck with a hammer, it broke up into small polygonal grains, just like those of the Cosby's Creek and Seelasgen meteorites.

Such products as have been described all point to a very slow cooling of the molten metal out of which the crystals came, and this is the opinion held by the best observers in regard to this process. Thus Mr. Sorby writes: "These facts clearly indicate that the Widmanstätt's figuring is the result of such a complete separation of the constituents, and perfect crystallization, as can occur only when the process takes place slowly and gradually. They appear to me to show that meteoric iron was kept for a long time at a heat just below the point of fusion, and that we should be by no means justified in concluding that it was not previously melted. Similar principles are applicable in the case of the iron masses found in Disco; and it by no means follows that they are meteoric, because they show the Widmanstätt's figuring. Difference in the rate of cooling would serve very well to explain the difference in the structure of some meteoric irons, which do not differ in chemical composition; but as far as the general structure is concerned, I think that we are quite at liberty to conclude that all may have been melted, if this will better explain other phenomena."[‡] Similar opinions have been expressed by Tschermak and Haidinger.

We have tried in this paper to establish the following points:—

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[*] Memoirs of the American Academy, New Series, vol. v, pp. 336–371.

[†] Ibid., vol. viii, pp. 27–56.

[‡] Nature, 1877, vol. xv, p. 498.

First. That many of the masses of meteoric iron in our collections are cleavage crystals, broken off probably by the impact of the mass against the atmosphere.

Secondly. That these masses show cleavages parallel to the planes of all the three fundamental forms of the isometric or regular system, namely, the octahedron, the cube, and the dodecahedron.

Thirdly. That the Widmanstättian figures and Neumann lines are sections of planes of crystalline growth parallel to the same three fundamental forms of the isometric system.

Fourthly. That on different sections of meteorites Widmanstättian figures and Neumann lines can be exhibited in every gradation, from the broadest bands to the finest markings, with no break where a natural line of division can be drawn.

Fifthly. That the features of the Widmanstättian figures are due to the eliminations of incompatible material during the process of crystallization.

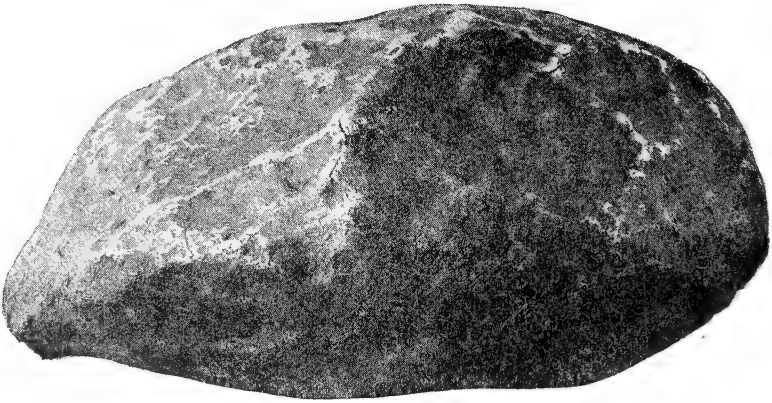
This investigation throws no new light upon the origin of meteorites, except so far as it strengthens the opinion that the process of crystallization must have been extremely slow. The occurrence of large masses of native iron occluding hydrogen gas, and containing nickel, cobalt, phosphorus, sulphur, etc., implies a combination of conditions which the spectroscope indicates as actually realized in our own sun and in other suns among the fixed stars, and the most probable theory seems to be that these masses were thrown off from such a sun, and that they very slowly cooled, while revolving in a zone of intense heat

In this paper we have not taken into consideration a number of iron masses, whose meteoric origin has been generally accepted, which show no Widmanstättian figures and not even any Neumann lines. A considerable proportion of these are certainly not meteoric. In the Harvard cabinet there are two specimens, labelled respectively Campbell County, Tennessee, and Hominy Creek, North Carolina, which are evidently nothing but cast-iron, and a third, labelled Tarapaca Hemalga, Chili, which is probably of similar material. We could find on the specimens of this class in the Harvard collection no distinct evidences of crystallization; but also we could find no features incompatible with that unity of structure which it has been the chief object of this paper to illustrate.

ART. XXXIV.—*A new Meteoric Iron from Texas;* by WM. EARL HIDDEN.

THE mass of meteoric iron described in this paper was discovered by Mr. C. C. Cusick, U. S. A., while he was stationed at Fort Duncan, Texas. He writes me a full account of the manner of the discovery, and I here give an abstract of his letter.

1.



The Maverick County, Texas, Meteoric Iron.
Weight ninety-seven pounds.
(ONE-THIRD NATURAL SIZE.)

"On the morning of June 10, 1882, being stationed at Fort Duncan, Maverick County, Texas (a military post situated on the left bank of the Rio Grande River), I was returning to the garrison from a short trip in the vicinity, when I casually noticed a round looking boulder that seemed to have a metallic appearance. I examined it more closely and found it in truth to be a metallic body and worthy of careful preservation. I early arrived at the conclusion that it was of meteoric origin as it possessed seemingly all the necessary characteristics of such bodies. I had it brought to the fort by one of the privates (Brand), who found the task not an easy one. It was kept at Fort Duncan until I moved to Fort Lyon, Bent Co., Colorado, where I am now stationed, and where this curiosity was for a long time on exhibition. It was on the land of a Mr. Wieste, on an ancient terrace on the American side of the river, near the fort, that I found this iron, and I would add, that he kindly presented the mass to me. I cannot learn anything as to the time of its fall, or its history, other than I have above given you."

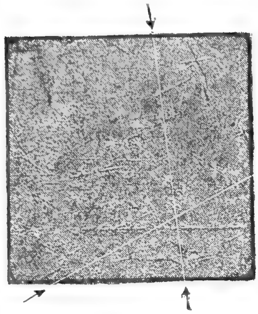
The writer received this meteorite in April of this year, direct from Mr. Cusick, having learned of its existence through the press. In size and weight it approaches very nearly that of Independence County, Ark., lately described; but differs from that iron very materially. It weighs ninety-seven and one-quarter pounds, and measures twelve by ten by six inches in its three diameters. Its shape is a nearly symmetrical ovoid, somewhat flattened, as shown in figure 1, which is one-third natural size. The surface is quite smooth and coated with the usual thin black crust characteristic of meteorites. Excepting where the mass has been rubbed the crust is uniform in thickness all over the mass and shows a slightly indented and blistered surface. The side which lay close to the ground (fig. 2) bears the only evidence of oxidation—a few rusty patches being seen there. This side—which I will call the under side—differs somewhat from the rest of the mass, in being more pitted and blistered. Two large depressions and three deep indentations are also noticed, in strong contrast with the smooth surface of the upper side. A few patches of calcium carbonate were also noticed adhering to the under side, but this must have been of terrestrial origin.

2.

Maverick Co., Texas, Meteoric Iron
(ONE-SIXTH SIZE.)

Upon etching a small surface, a peculiar appearance, unlike anything the writer has seen in meteoric irons, presents itself to view. No Widmanstättian figures are present except in traces and even these are very dim. The particular markings to which I call attention are two series of fine lines, looking much like rulings, that cross each other at angles of 70° and 110°. These lines appear very bright when viewed in certain lights. As no troilite nor schreibersite shows itself as the cause of these striations, I conclude they are due to twinning lamellæ. I have found that if the surface is etched deeply, these lines (striations) disappear, and a new set of markings appear. These markings are composed of minute lamellæ of schreibersite arranged in short lines diverging at all angles, and have much the appearance, when magnified, of the quartz in graphic granite. To a hasty observer this iron would appear only slightly mottled when etched, and indeed it is necessary to magnify its surface five or more diameters before its interesting features can be appreciated. In figure 3 an effort is made to illustrate, by

3.



Structure of Maverick Co. Iron.

the photo-engraving process, the result from etching this iron, but it only partly succeeds in its object. This plate is three times natural size. The white lines with arrows indicate the directions of the fine lines which covered the whole surface of the iron previous to the last etching.

On a surface, five inches long (bottom of figure 2), which was smoothed and polished nearly four years ago, a small nodule of troilite was noticed, and two small fissures filled with graphitic carbon. This surface showed the metal to be of unusual whiteness; more like the luster of mercury than any iron the writer has seen. The iron is quite soft, being easily cut with a knife. Sp. grav., 7·522. The composition, as shown by Mr. J. B. Mackintosh, E. M., in an analysis just completed, is: Iron 94·90 per cent, phosphorus 0·23 per cent, nickel and cobalt (by difference) 4·87 per cent=100·00 per cent, sulphur and carbon in traces.

This iron, which will henceforth be known under the name of the *Maverick County Meteorite*, was found more than one hundred miles in a due east direction from the famous Butcher Irons from Coahuila* and that from the Sancha estate,† Mexico; both described by Smith. But the density and composition of these last two irons show marked differences from that of Maverick County, Texas. "The Sancha iron had a density of 7·81 and presented the figures of Widmanstätt similar to that of the Braunau iron" (Smith). The smooth surface and regular form of this iron from Maverick County would also preclude its being a part of another fall, as it seems to be complete in itself.

The representation which Brezina gives‡ of the iron from Hex River Mountains (South Africa) resembles in its crystalline structure and inclusions the iron here described, in a marked degree. It is also near to, if not similar with, the class of meteoric irons, to which belong those from Auburn, Ala.,§ and Davidson County, N. C.‖ This is the fourth mass of meteoric iron discovered in Texas. The others being known as the Gibbs or Red River,¶ the Denton County,** and the Wichita County†† irons

Newark, N. J., June 12, 1886.

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* This Journal, vol. xlvii, p. 383–385. † Ibid, vol. xix, p. 151–323.

‡ Die Meteoritensammlung des k. k. mineralogischen Hof-kabinets in Wien am 1. Mai, 1885. Tafel 3, fig. 5. § Ibid, vol. xlvii, p. 230.

‖ Ibid, III, vol. xx, p. 324. ¶ Ibid, I, vol. viii, p. 218.

** Trans. St. Louis Acad. Sci., 1857–60, vol. i, p. 623.

†† Ibid, p. 622, and this Journal, III, vol. xxviii, p. 285.

ART. XXXV.—*On Pseudomorphs of Garnet from Lake Superior and Salida, Colorado;* by S. L. PENFIELD and F. L. SPERRY.

1. *Garnets from Lake Superior.*

THE decomposed garnets from the Lake Superior region form quite common specimens in the mineralogical collections of this country. A description and microscopical examination of these garnet crystals have been made by Mr. Raphael Pumpelly.* According to Mr. Pumpelly, "these pseudomorphs of garnets occur in abundance in a bed of chloritic schist just overlying the great magnetite bed of the Spurr-Michigamme iron range." He calls the decomposition product, and also the material in which the crystals are imbedded, chlorite. But he gives no analyses to indicate its relations to the garnet.

Our examination of these pseudomorph garnets was made on crystals from a suite in the mineralogical collection of Professor Geo. J. Brush, to whom we take great pleasure in expressing our thanks for the material kindly placed at our disposal. The crystals are invariably dodecahedral. Many of them show interesting distorted forms. We first took the specific gravity of twenty of the best crystals, which were found to vary between 4·11 and 3·22. As would be expected, a close examination proved the heaviest crystals to be nearly pure garnet, while the lightest ones were almost wholly the decomposition product. This wide variation in specific gravity not only indicates the unequal extent to which the decomposition has gone on, but also guided us in selecting material for analysis.

In order to study the decomposition of the garnet, an analysis of the pure garnet was made. The material was taken from partially decomposed imbedded crystals. The heavier garnet was obtained, nearly pure, by means of the cadmium-borotungstate solution. An examination with the microscope revealed some of the green decomposition-product still adhering to and penetrating the garnet. The heavy powder, thus separated, was boiled with sulphuric and hydrochloric acids to decompose the chlorite and then with caustic potash to dissolve any separated silica. The garnet obtained had a light pink color and appeared to be very pure on examination with the microscope. The analysis is given below under I. It will be seen that it is essentially an iron alumina garnet, having this formula—$Fe_3Al_2Si_3O_{12}$, part of the iron being replaced by Ca, Mg and Mn. The ratio of $SiO_2 : Al_2O_3 : RO$ is 3 : ·96 : 2·87; required, 3 : 1 : 3.

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* This Journal, III, x, 17.

The analysis of the decomposition product was made from a selected fragmentary crystal having a specific gravity of 3·281. It was part of a large dodecahedron. Along the fracture it showed numerous little octahedrons of magnetite and a foliated structure of the chloritic material. A microscopical examination revealed the presence of a very little unaltered garnet. A mechanical analysis showed that there were 3·23 per cent of unaltered garnet and 3·28 per cent of magnetite in this decomposed product. The magnetite was carefully extracted with a strong magnet, and the garnet was obtained by a process similar to that mentioned above in the preparation of the pure garnet. The analysis is given below under II after deducting 3·23 per cent of garnet. A second decomposed crystal having a specific gravity of 3·22 was also analyzed. The material was obtained by powdering the crystal and sifting through a sixty-mesh sieve. The material was then suspended in water. The garnet was allowed to settle out and the light chlorite scales decanted off and collected in a platinum dish. The material was obtained in a nearly pure state. The analysis is given under III after deducting ·46 per cent of garnet.

Analyses of garnet and decomposition product from Lake Superior.

		I.	II.	III.
		Garnet.	Decomposition products.	
SiO_2	=	38·03 per cent.	27·45 per cent.	29·08 per cent.
Al_2O_3	=	20·83	19·53	19·94
Fe_2O_3	=	----	6·26	3·91
FeO	=	36·15	29·42	30·48
MnO	=	2·14	----	·20
MgO	=	·97	6·04	5·56
CaO	=	2·73	----	·25
Na_2O	=	----	·42	·29
K_2O	=	----	2·64	3·66
H_2O	=	----	7·50	6·53
		100·85	99·26	99·90

No. II had specific gravity of 3·21, calculating it free from garnet and magnetite.

On comparing the above analyses, it will be seen that the following changes have taken place in the garnet: a slight oxidation of the iron, a decrease of nearly 10 per cent in silica, an almost total disappearance of manganese and calcium, and an increase in magnesium, alkalies and water. With the exception of the silica and water the change has not been very great. As regards the nature of the decomposition product, it is not an ordinary magnesium chlorite, such as ripidolite or penninite, but is essentially a ferrous chlorite, closely related to prochlorite, or more nearly to Sandberger's aphrosiderite. We find by calculating the ratios of analyses II and III that the elements are united in the following proportions:

	SiO_2	R_2O_3	RO	H_2O	
II =	4	1·97	5·11	3·49	
III =	4	1·80	5·06	3·00	or nearly
	4	2·	5·	3·	

Groth* gives the ratio of aphrosiderite as

SiO_2	R_2O_3	Ro	H_2O
4	2	6	5

But analyses from different localities vary to quite a large extent, and Sandberger's analysis shows less water than is required by Groth's formula. A little admixture of ripidolite having a ratio of 4 : 2 :: 6·66 : 6† would materially alter the proportion of RO : H_2O in aphrosiderite, and a little admixture of free silica would account for the excess of SiO_2. It is not probable that the potash belongs to muscovite, which is mechanically mixed with the aphrosiderite. In the first place, a microscopical examination reveals no muscovite, and secondly, by calculating out 22 per cent of muscovite, the amount required by the potash in analysis II and 31 per cent in analysis III, the elements left would be too low in sesquioxides and very much too high in protoxides to be referred to any known species of chlorite.

The matrix.—The material in which the garnets are imbedded appears to be very homogeneous, when examined in thin sections under the microscope, appearing as a mass of minute, pleochroic green scales in which an occasional grain of magnetite is imbedded. An analysis shows that it is also a ferrous chlorite differing from the alteration product of the garnet and agreeing closely with thuringite. The analysis gave:

	I.	II.	Mean.	Mol. ratio.		
SiO_2 =	22·45 per cent.	22·26 per cent.	22·35 per cent. =	·3725	= 3·	3
Al_2O_3 =	25·23	25·05	25·14 =	·244	= 1·98	2
FeO =	34·34	34·43	34 39 =	·447	= 5·15	5
MnO =	trace	----	----			
MgO =	6·31	6·51	6·41 =	·161		
H_2O =	11·25	11·25	11·25 =	·625	= 5·04	5
	99·58	99·50	99·54			

The ratio $SiO_2 : Al_2O_3 : RO : H_2O = 3 : 2 : 5 : 5$ does not quite agree with Rammelsberg's ratio for thuringite, 3 : 2 : 4 : 4, but

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* Tabellarische Uebersicht der Mineralien. Zweite Auflage, 1882.

† Taken in this form for easier comparison.

the ratios are sufficiently close to justify us in referring the material to that species.

It should be stated that all these analyses were made in duplicate from carefully selected air-dried material, none of which lost more than 0·10 per cent at 100° C. Fe_2O_3 was determined in every case when present. Although these analyses do not indicate well-defined species, they show clearly what changes the garnet has undergone. The microscopical examination did not reveal anything not noticed by Mr. Pumpelly in his article already referred to.

2. *Decomposed garnets from Colorado.*

We have also examined the pseudomorph garnets from Salida, Chaffee Co., Colorado. The garnets were large dodecahedrons coated with chlorite. They differ from the Lake Superior garnets in that the decomposition forms only a coating, while the interior of the garnet crystal is quite homogeneous. One large crystal, 7^{cm} in diameter, is in the collection of Professor Geo. J. Brush. We are indebted to Mr. Whitman Cross of the U. S. Geological Survey for information concerning the correct locality in which these specimens occur, and to Mr. L. G. Eakins for the material which he kindly procured for us from a mineral dealer in Colorado. The material was obtained by scraping off the thin coating of chlorite, which was readily removed from the hard garnet. The analyses of this material are given below.

	Garnet. Specific gravity 4·163.	Decomposition product after deducting 1·04 per cent of garnet.
SiO_2	= 37·61 per cent.	28·20 per cent.
Al_2O_3	= 22·70	22·31
Fe_2O_3	----	----
FeO	= 33·83	19·11
MnO	= 1·12	----
MgO	= 3·61	17·68
CaO	= 1·44	·48
Na_2O	----	·72
K_2O	----	1·03
H_2O	----	10·90
	100·31	100·43

From the above analyses, it will be seen what changes have taken place here. It is essentially the same change that the Lake Superior garnet has undergone, with the exception that a greater quantity of magnesium has replaced the protoxide of iron. The ratios of the above analyses are:

	SiO_2	: Al_2O_3	: : RO	: H_2O
Garnet........... =	3	: 1·05	: : 2·88	
Decomp. product =	4	: 1·84	: : 6·25	: 5·08

The garnet ratios agree closely with the theoretical. The ratios of the alteration product agree closely with Groth's formula for aphrosiderite. It is higher in protoxides and water than the Lake Superior specimens, but it may be the same compound mixed with ripidolite, which would account for this increase. No microscopic section of this decomposed product was made. Some of the larger scales showed, in convergent light, the dark cross and interference figure of a uniaxial crystal. The color of the aphrosiderite is light green, much lighter than that from the Lake Superior locality.

The changes which have previously been noted in garnet differ from ours, in that they have been the alteration of pyrope (magnesia garnet) into ripidolite or serpentine-like magnesia silicates.

Mineralogical Laboratory, Sheffield Scientific School, New Haven, May 18, 1886.

Art. XXXVI.—*Further notes on the Meteoric Iron from Glorieta Mt., New Mexico;* by George F. Kunz. With Plates V to VII.*

Since the publication of the article on the three masses of meteoric iron from Glorieta Mt.,† New Mexico, Mr. J. H. Bullock has very kindly furnished me with the information wanting; it has been found impossible to communicate with Mr. Charles Sponsler. During the month of August, 1885, Mr. Bullock thoroughly examined and dug over the ground, working about six weeks steadily, and was rewarded by finding three more masses of the Glorieta meteorite (Nos. 4, 5, 6). In the meantime a Mexican had also found a small piece (making seven fragments thus far obtained), but it disappeared before Mr. Bullock could secure it. Mr. Bullock states that the pieces found by Mr. Sponsler were discovered while he was prospecting during the month of August, 1884, on the ranch of Mrs. Roival, near Canoncito, Sante Fe Co., N. M., five miles from the summit of Glorieta Mt.

No. 4 weighs 1·204 kilos (2·65 lbs.). One-third of the surface shows the disruption, as in No. 2, the other parts being unaffected and showing the crust surface. The broken surface is partially drawn out toward the part that was torn off from it,

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* By a mistake of the binder, plate VII was inserted in the September number.

† This Journal, III, xxx, 235.

and one edge shows a fracture suggesting cleavage. The mass is 50^{mm} high, 125^{mm} long and 50^{mm} wide, or about 2×5×2 inches. One of the pittings, which has been increased in size by the disruption, measures 60^{mm} in length, 25^{mm} in width, and 15^{mm} in breadth (see plates V and VI).

No. 5 weighs 1·126 (2·48 lbs.), measures 100^{mm} in length, 75^{mm} in width and 48^{mm} in height, about 4×3×2 inches. Five-sixths of the entire surface bears marks of the violent disruption; the mass was undoubtedly broken from the upper corner between Nos. 1 and 3. A raised octahedral structure, resembling a coarse network, is revealed on two-thirds of its surface, and the pitted side shows evidence of having received a part of the blow (see plates V and VI).

No. 6 weighs 1·05 kilos., measures 125^{mm} in length, 82^{mm} in width and 45^{mm} in thickness at the thickest part. It is quite flat, the fracture having left a surface so flat as to be suggestive of a cleavage. Altogether this mass closely resembles No. 4 (see plates V and VI).

The 148½ lb. (No. 1) piece was found only eight feet from the 115 lb. (No. 2) and 53½ lb. (No. 3) pieces, while the small pieces picked up by Bullock and the Mexican were 45 or 50 feet from the large mass, being hurled farther on account of their lightness. The fact that the pieces lay so near together proves conclusively that the meteorite did not burst in mid air. The pieces were all imbedded in the vegetable mould which covered the rock at that place, the largest piece to the depth of ten inches.

Nearly the whole of the large mass (No. 1) has been cut into slices. The iron is seen to be very homogeneous throughout with the exception of an occasional space measuring 1^{mm} to 4^{mm} across. One of these spaces near the center of the mass was evidently formed by the shock of disruption. In a few instances this explanation is verified by a palpable curving of the Widmanstättian figures, showing that nearly every part of the thick mass was twisted and wrenched, when it burst asunder with such tremendous force. The ruptured surface on Nos. 1 and 3 shows large patches of troilite. In cutting No. 1 large streaks of this mineral and also some schreibersite were observed. The largest of these lines of troilite was 10^{cm} long and 4^{mm} wide. Two of the streaks, 10^{cm} apart, ran parallel to each other in peculiar crescent-like formations. Olivine was observed at the upper end of No. 1, a surface about 10^{cm} square being completely filled with it. The color in some instances was a rich brownish yellow, homogeneous throughout, and as compact as in the "Pallas Iron." The largest grains observed measured from 8^{mm} to 14^{mm}. Some of these pieces yielded perfect *transparent gems* (peridots) over 4^{mm} in width.

The large plate (VII) is an exact reproduction of the largest section of mass No. 1. It was made after several experimental attempts by a new process devised by the writer (see A. A. A. S. Rep., 1886). The whole of the iron was sunk into wax, except the surface to be reproduced; this was dusted with graphite, and the copper thrown down on this, producing what is termed a negative electrotype; this, when the unevenness is removed, prints an exact facsimile of the Widmanstättian figures, more accurately and at only one-sixth to one-eighth the cost of any other process. This is the largest etched surface that has ever been faithfully reproduced.

I was kindly informed by Dr. Whitman Cross, of Denver, Col., that on Oct. 6, 1884, a meteorite was presented to the Colorado Scientific Society with descriptive remarks by Mr. Richard Pearce of the Boston and Colorado Silver Mining Co. It was sent to the company from Albuquerque, N. M., as silver bullion,—and could not be traced further back,—although it was probably found in the vicinity of the place from which it was forwarded. Its weight before cutting was about 2·5 kilograms, and its dimensions were $48 \times 80 \times 100^{mm}$. A short paper upon this meteorite was read before the Colorado Scientific Society on June 1, 1885, by Mr. L. G. Eakins of the Geological Survey, This paper contains an analysis of the iron, which is subjoined:

Fe	88·760*
Ni	9·860
Co	0·510
Cu	0·034
Zn	0·030
Cr	trace
Mn	"
C	0·410
P	0·182
S	0·012
Si	0·044
	99·842

This paper by Mr. Eakins appeared in the Proceedings of Col. Sci. Soc. for 1885 and these figures were kindly furnished by him. The striking similarity between this analysis and that of the Glorieta meteorite leads me to believe that this iron is the seventh fragment of the Glorieta meteorite, which was found by the Mexican, and that he mistook it for silver bullion and sold it as such.

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* Mean of 88·66, 88·77, 88·84.

ART. XXXVII.—*On the Brookite from Magnet Cove, Arkansas;* by EDWARD S. DANA. With Plates VIII and IX.

THE species brookite is interesting, among other respects, because of the great variety of form exhibited by the crystals from the different localities at which it occurs. This fact is well exhibited in the figures on Plate XXXIX, of Schrauf's Atlas. In this regard the crystals from Magnet Cove, Arkansas, are especially remarkable, for though the number of planes observed on them is not large, the variation in habit is most unusual for crystals from a single locality.

The brookite from Magnet Cove was first mentioned by Shepard* in 1846, who supposed it to be a new species and gave to it the name *arkansite.* In 1876 vom Rath† gave an interesting account of the paramorphs of rutile after brookite, which are not rare at this locality, and also figured several of the common forms. A few months since S. L. Penfield‡ published a paper upon the arkansite in which he gave figures of four forms, and also the results of measurements of a crystal of unusual perfection. It might seem perhaps as if these papers had exhausted the interest of the subject; and this may be true so far as the commonly occurring types of forms are concerned. Through the kindness of Mr. Clarence S. Bement of Philadelphia, the writer has had the opportunity of studying his large series of crystals of this species, and the variety among them has been found to be so great that they have seemed worthy of special description, with also some fullness of illustration. These crystals have been selected from time to time with great care from a large amount of material, and they represent the best specimens which the locality has afforded. Most of the crystals are isolated, the arkansite occurring chiefly in loose crystals scattered through the soil.

The planes which have been determined on these crystals are as follows:

Pinacoids, *a* (100, $i\text{-}\bar{\imath}$), *c* (001, *O*); prisms, *l* (210, $i\text{-}\bar{2}$), *m* (110, *I*), ϕ (120, $i\text{-}\breve{2}$), new; brachydome, *t* (021, $2\text{-}\breve{\imath}$); pyramids, *z* (112, $\frac{1}{2}$), χ (124, $\frac{1}{2}\text{-}\breve{2}$), *Q* (234, $\frac{3}{4}\text{-}\frac{3}{2}$), *e* (122, $1\text{-}\breve{2}$).

The crystals may be roughly divided into those of prismatic, and others of pyramidal habit. In the former, figures 1 to 12, with also figs. 14, 15, 16, 18, (Plates VIII, IX), the fundamental prism, *m*, usually predominates; the forms vary much, however, according to the pyramid by which they are terminated. Figure 1 is a common form, occurring in crystals of relatively

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* Am. Journ. Sc., II, ii, 250, 1846.

† Pogg. Ann., clviii, 407, 1876.

‡ Am. Jour. Sc., III, xxxi, 387, 1886.

large size, sometimes 1 to 2 inches in length; here the pyramid *z* (112, $\frac{1}{2}$) is alone present. This form, though so simple, is interesting because of the similarity it bears to a common form of rutile, the allied species, also TiO_2 in composition. This resemblance is apparent at once, as was remarked by vom Rath, and is in a measure borne out by the angles of the two species. In rutile the prism is one of 90° and the pyramid *s* (111, 1) is a tetragonal pyramid with a terminal angle of 56° 52½′; in this related orthorhombic form the prismatic angle is 80° 10′ and 99° 50′ and the pyramid *z* has terminal angles of 53° 48′ and 44° 46′, calculated from the measurements by von Kokscharow on the usual assumption that the species is orthorhombic. It is interesting to note that this type of crystal is the one which most frequently shows the paramorphic change to rutile. Figure 4 represents a form much like that just alluded to but showing also the common brachy-pyramid *e* (122, $1\text{-}\breve{2}$) which by some authors is made the unit pyramid. Figures 2 and 3 show other crystals much smaller, and marked by the presence of the basal pinacoid. The crystals, represented in figures 5 to 8, were small, about $\frac{1}{3}$ to $\frac{1}{2}$ inch in length, and of a rich reddish brown color, different from the common color of the crystals of the locality, which is deep black. The pyramid which predominates here, sometimes to the obliteration of other terminal faces, is the obtuse brachy-pyramid χ (124, $\frac{1}{2}\text{-}\breve{2}$) with terminal angles of 48° 54′$=\chi\chi'''$ ($124 \wedge 1\bar{2}4$), and 28° 28′$=\chi\chi'$ ($124 \wedge \bar{1}24$). The planes *z* and χ are often striated deeply, parallel to their mutual intersections, and the oscillatory combination of these planes is sometimes so marked that the termination appears to be made by two brachydomes. Figure 6 is a basal projection of a crystal near that shown in fig. 5, but having also the planes *c* and *e*.

The crystal drawn in figs. 7 and 8 is interesting as showing the rare plane *Q* (234, $\frac{3}{4}\text{-}\breve{\frac{3}{2}}$) in the zones *z*, *e* and χ, *m*. This plane has not been observed before at this locality, and has only been noted by Groth and Bücking* on a crystal from the Maderanerthal. Figure 16 shows another prismatic form with an acute termination formed by the dome *t* and the pyramid *e*. Figures 14 and 15 represent a short prismatic form of unusual complexity; fig. 25 (after Penfield) is a basal projection of an allied form, but one in which the pyramid χ is a narrow bevelment of the brachy-diagonal terminal edge of *z*, much as *z* bevels the macro-edge of *e*.

Figures 11 and 12 represent a rare type of form in which with the unit prism we have also the prisms *l* (210, $i\text{-}\bar{2}$) and φ (120, $i\text{-}\breve{2}$). This last plane is a new one for the species; it was determined by the measured angles:

$\phi\,\phi' = 120 \wedge \bar{1}20 = 62° 1'$; 61° 26′ calculated (Kokscharow).

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* Mineralien-Sammlung, Strassburg, p. 110, 1878.

In figures 9 and 10 a common type of crystal is represented in which the macro-prism *l* predominates. These crystals are often quite flat parallel to the macropinacoid from the oscillatory combination of the two prisms *l* and *m*, and the termination is often formed by narrow faces of the pyramid *e*. In fig. 18 the prism *l* is alone and the appearance of the crystal is strongly in contrast to the stout nearly square prisms of figs. 1, 2, etc.

The remainder of the crystals figured are essentially pyramidal in type. The most interesting of these is figure 17, in which the planes *m* and *e* are "in equilibrium" and thus form a nearly regular hexagonal pyramid. This is one of the most common and striking types occurring at the locality; many of the crystals occurring implanted upon massive quartz have this habit. The front edge of the prism *m* is not infrequently truncated by the macropinacoid *a*, and sometimes the planes *c*, *z*, χ and *t* are also present as shown in figs. 20, 22, 23: these more complex forms still preserve the hexagonal aspect by the predomination of *e* and *m*. Fig. 19 is a form, observed by Penfield, of small crystals implanted thickly on a porous siliceous gangue.

In fig. 21 a form is shown in which the pyramid *e* predominates, only modified by *z* and *m*; in fig. 24 *m* is absent and only the pyramid *e* present with its front edge beveled by *z*. The ordinary projection, used in fig. 21, fails to give the true effect of this type, which is that of an acute nearly square pyramid, elongated in the direction of the $\breve{a}$ axis. The shape is better exhibited in the basal projection of fig. 24. This form is interesting in the same way as fig. 1, in that it approximates in form and angle to the common acute octahedron of the third form of titanium dioxide, octahedrite. The pyramidal angles of the latter species are 82° 9′, 82° 9′ and 43° 24′ (basal), while the corresponding angles of brookite are 84° 38′, 78° 57′ and 44° 23′. This type of crystal is often altered to rutile. It may be added that the crystal figured in 24 was most strikingly like the pseudomorphs of wolfram after scheelite from Monroe, Connecticut.

As has been remarked by Penfield, the brookite from Magnet Cove is ill adapted for close measurements. Many of the planes are striated, as those of the prismatic zone, and those of the zone *z*, χ, χ', *z′*. Even when the planes are seemingly smooth they give uncertain or multiple reflections. The following measurements obtained from the best of the crystals under examination, are however, worth recording, though not deserving of great weight.

			Measured.	Calculated (Kokscharow).
$\chi\chi'$	$124 \wedge \bar{1}24$	=	28° 46′	28° 28′
$\chi''\chi'''$	$1\bar{2}4 \wedge \bar{1}\bar{2}4$	=	28° 31′	
$\chi\chi''$	$124 \wedge 1\bar{2}4$	=	48° 44′	48° 54′
$\chi'\chi'''$	$\bar{1}24 \wedge \bar{1}\bar{2}4$	=	48° 55′	
zz'	$112 \wedge \bar{1}12$	=	53° 47′	53° 48′
$z''z'''$	$112 \wedge \bar{1}\bar{1}2$	=	53° 44′	
zz''	$112 \wedge 1\bar{1}2$	=	44° 45′	44° 46′
$z'z'''$	$\bar{1}12 \wedge \bar{1}\bar{1}2$	=	44° 46′	
mm'''	$110 \wedge 1\bar{1}0$	=	79° 25′	80° 10′

A comparison of these angles and of those obtained by Penfield shows a considerable variation among themselves; while on the whole they correspond tolerably well with the measurements by Kokscharow of Russian crystals.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY.

1. *Contributions from Chemical Laboratory of Harvard College,* under the direction of Professor COOKE.*—Mr. GEORGE W. LEIGHTON has made an *analysis of a mica from Leon Co., Texas,* which attracted notice as it presented characters intermediate between those of the vermiculites and the muscovites. The mica is opaque except in thin laminæ and has obviously undergone alteration. Cleavage basal, eminent; laminæ flexible, but brittle and non-elastic. Luster pearly. Color brownish to yellowish green. Double refraction negative. Biaxial; with bisectrix nearly if not absolutely normal to the cleavage, the optical angle in air measuring about 37½°, but could not be measured accurately on account of opacity. In blowpipe flame the laminæ separate, swelling to more than double the original thickness, and melting on the edges, showing fusibility 5–6. Blowpipe flame strongly colored with potash, barely tinged with soda, and with traces of lithia. No fluorine could be detected by the usual tests.

The analysis was made in the usual way, fusing with Na_2CO_3 for the silica, decomposing with HF for the alumina, iron, and magnesia, and by Lawrence Smith's method for the alkalies. The iron was all in the ferric condition, and was determined volumetrically after weighing Al_2O_3 and Fe_2O_3 together. The potash was weighed as chloroplatinate, and the water was determined by ignition. In the following table, the results of the analysis are given in column I. In column II, are the corresponding per cents of oxygen, and in column III, are given for comparison the results of an analysis of a mica from Hirschburg, taken from Dana's System of Mineralogy, last edition, and classed by him among the muscovites.

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* Proceedings of the American Academy of Arts and Sciences, vol. xxii, 158.

	I.	II.	III.
SiO_2	48·95	26·11	49·04
Al_2O_3	25·17	11·73	29·01
Fe_2O_3	9·40	2·82	5·56
MgO	1·69	0·67	0·75
CuO	trace.	----	0·17
Na_2O	trace.	----	0·50
K_2O	11·08	1·88	11·19
H_2O	4·31	3·83	4·65
	100·60		100·87

Oxygen Ratios.—Bases with water to silica are as 4:5 nearly. Bases without water to silica are as 2:3 approximately.

$$RO+H_2O : R_2O_3 : SiO_2 = 5 : 11 : 20.$$
$$RO : R_2O_3 : SiO_2 = 2 : 11 : 20.$$

As will be seen the composition of the Texas mica agrees very closely with that of the mica from Hirschburg. It is an evident product of alteration, with some of the characters of a vermiculite, and differs in composition from ordinary muscovite only in the absence of the fluorine, and the presence of a somewhat larger amount of magnesia. It appears as if it were an early stage in the alteration of muscovite to vermiculite.

Mr. Leighton has also made the *analysis of a crystalline scale formed in the manufacture of sodium bicarbonate by the ammonia process* at Syracuse, N. Y. This scale was deposited on the inner surface of an iron tank in which vapors consisting of ammonia, carbonic dioxide, with small quantities of hydric sulphide are passed through brine holding in solution the chlorides of sodium, magnesium and calcium, with a small amount of calcic sulphate. It has the appearance of a boiler scale from one to two inches thick, with a vitreous luster and a greenish gray color, although sometimes black on the surface. The scale is usually covered with crystal planes which have at first sight the appearance of octahedral forms projecting from the surface, but on closer examination the planes were found to be the termination of prisms (probably monoclinic) extending down into the body of the scale. For the details of the crystallographic work as well as for the methods of analysis we must refer to the original paper. From the means of many determinations the following general result was deduced:

	Found.	Theory.	Diff.
NaCl	22·230	22·23	
Na_2CO_3	40·622	40·28	−0·34
$MgCO_3$	31·569	31·92	+0·35
$CaCO_3$	3·559		
$FeCO_3$	0·080		
H_2O	0·630		
CO_2 in excess	0·645		
	99·335		

The scale is evidently a triple salt represented by the symbol $MgCO_3 . Na_2CO_3 . NaCl$ mixed with small amount of impurities, and how closely the analysis corresponds to this theory is shown by the second column of figures. That the common salt is combined and not simply mixed with the double carbonate appears not only from the definite proportion, but also from the fact that the material is so slowly acted on by water. Evidently we have here a definite crystalline product of a very interesting constitution not unlike that of several well defined mineral species in which an alkaline chloride appears to be in molecular union with heterogeneous materials having a function not unlike that of water of crystallization.

Mr. THEODORE W. RICHARDS has made a very extended series of observations of the *heat produced by the reaction of argentic nitrate on aqueous solutions of metallic chlorides* and found that the quantity of heat evolved was directly proportional to the amount of silver nitrate used. As the investigation was a question of comparison rather than of absolute measures it was possible by keeping the conditions as uniform as possible to obtain results which were strictly comparable. The method is described and the results are given in detail in the papers above referred to and it appears that all of these results are identical within the limit of error of the process. We may, therefore, draw the conclusion, that the amount of heat evolved by the reaction thus represented,

$$(\tfrac{1}{n}R_m\,\mathrm{Cl}_n+\mathrm{AgNO}_3+\mathrm{Aq}) = \mathrm{AgCl}+(\tfrac{1}{n}R_m(\mathrm{NO}_3)_n+\mathrm{Aq}),$$

is constant, no matter what R, m, or n may be.

Hence, also, *the difference between the heats of formation of equivalent amounts of nitrate and chlorides in aqueous solution is the same for any metal or basic radical.*

Mr. IRVING W. FAY made a similar investigation on the heat of formation of chlorides and sulphates in aqueous solution involving the general factors

$$\tfrac{1}{n}R_m\,(\mathrm{SO}_4)_n+\mathrm{BaCl}_2\,.\,2\mathrm{H}_2\mathrm{O},$$

but the same constancy in the heat of the reaction was not found. From the table of results which is given in the original paper it appears that the difference between the heats of formation of of chlorides and *sulphates* is *not* the same for all metals, as it was found to be in the case of the chlorides and *nitrates.* It appears, however, that with sulphates of allied bases the agreement is as close as before, but the sesquioxide salts give a larger amount of heat than the protoxide, and the double salts a still larger quantity, and sulphuric acid much the largest of all. It is a singular fact, that in the case of common alum the heat evolved is greater than it is with either of its constituent salts. J. P. C.

II. GEOLOGY AND NATURAL HISTORY.

1. *Brief Notices of papers read before the Geological Section of the American Association.* Communicated to this Journal by Professor W. M. DAVIS.—

Testing the Durability of Building Stones.—A paper by A. A. JULIEN treated of methods of testing building stones for absorption, freezing and fire. As an allowance of ninety per cent is now made by architects for error in the values of crushing strength ordinarily quoted, the author desired to devise tests that more closely measure the characteristics of stone under natural conditions; he said that strength should be determined by moderate, long-continued pressure that causes a slow yielding, rather than by heavy, violent pressure that produces immediate crushing; that the stone should be continued under pressure at least a month. Frost was found to be more active in removing particles that had been loosened by chemical weathering than in direct mechanical breaking of unweathered rock.

Geology of Southwestern Colorado.—The geological features of a district in southwestern Colorado were described by Dr. T. B. COMSTOCK in several papers. The mines of Red Mountain are found to be situated in a region of extinct geysers, many mounds around the old vents being larger than any now known in the Yellowstone Park; the galleries opened in them give excellent opportunity for the study of geyser structure and of mineral deposition along the old conduits. The distribution of lavas in the same region suggested a mechanical explanation for von Richthofen's classification of volcanic rocks, which Dr. Comstock accepts with certain modifications; andesites are ejected early near the base of large folds; and if the need of escape from compression be great and long-continued, trachyte and rhyolite and finally basalt may follow. He observed that existing examples clearly show this sequence. The local glacial drift and the veins of the region were also described.

Tully Limestone.—S. G. WILLIAMS, of Cornell, detailed the outcrop and thickness of the Tully limestone in the neighborhood of the finger lakes of western New York, where its eroded margin follows a sinuous line. Its gentle dip to the south is occasionally varied by faint curvature in the form of very flat broad-span arches. A list of one hundred and sixteen fossils was presented as representing its fauna. E. W. Claypole referred to a bed in Pennsylvania that he had thought to be the equivalent of the Tully limestone in New York, and believed his opinion confirmed by the fossils of this list. H. S. Williams thought that nearly all these fossils belonged to the calcareous Hamilton beds that occurred near the true Tully limestone, which he regarded as poor in fossils.

Mollusca of the New Jersey Marls.—R. P. WHITFIELD, in a paper on the molluscan fauna of the New Jersey marls, gave reasons for belief that the Cretaceous members are equivalents of the higher members (Nos. 4 and 5) of the upper Missouri section, and that the Eocene beds are nearly coeval with the Claiborne beds of the south. The distinctive features of these studies are the gathering together of the material and its separation into paleontological horizons corresponding with those determined stratigraphically by the State geologist. The list of species includes 224 Lamellibranchs, of which 74 are new, and 132 Gasteropods, of which 66 are new: Cephalopods and Brachiopods are relatively poor in species.

New York Devonian Geology.—H. S. Williams, of Cornell, presented a revision of the Cayuga Lake (N. Y.) Section of Devonian, and reached the conclusion that the Hamilton fauna was not interrupted by the limestones associated with the Coralline beds, and that the Moscow shales also include only a modified stage of the Hamilton fauna, but that the true Tully limestone, whenever it is distinct, interrupts the Hamilton fauna, and is associated locally at least with the overlying deposits called Genesee, with which it should be connected more intimately than with the Hamilton below.

A second paper by the same author, based on his paleontological studies, and illustrated especially by species of Strophomenidæ, described the initiation of genera and species in the geological series. Wide variation was found to be developed soon after the first appearance, and species in later horizons did not seem to accumulate additional variation, but rather to persist in forms previously defined: a genus thus appears plastic at first, and fixed afterward.

Mr. Walcott mentioned that the trilobites present similar characteristics in their first appearance and later continuation.

Connecticut Valley Triassic.—A process of mechanical deformation for the Connecticut valley Triassic formation was suggested by W. M. Davis, of Harvard, and illustrated by a working model. [The paper will appear in the following number of this volume.] Its essential suggestion was that the faulted monoclinal structure now possessed by the surface covering of Triassic strata was due to their accommodating themselves to the deformation of the floor of tilted schists and gneisses on which they rest. Professor Newberry thought the suggestion would aid the solution of the old Triassic problem, but doubted the occurrence of the reversed faults that it involved; and Professor Emerson believed that it might find support in the attitude of the Triassic beds in Massachusetts, although they presented more irregularity than those of Connecticut.

Nebraska Geology.—Professor L. E. Hicks reported upon several lines of work that are occupying him in Nebraska. A geological map of the eastern part of the State was first presented in order to give proper relation to the later papers. A series of beds conformably overlying the coal measures, and unconformably covered by members of the Cretaceous formation, was called Permian provisionally, and fossils collected from it by Mr. W. C. Knight were exhibited, among which there were several new types and but few forms known from the coal measures. Professor Newberry questioned the propriety of calling these beds Permian; he knew of no American equivalent of true European Permian, as determined by fossils. Mr. Walcott, on the other hand, had regarded certain beds in Arizona as good representatives of the formation in question. Mr. Davis asked whether the speakers agreed in regarding Permian as a division of geological time or as the name for a deposit holding a certain fauna. Professor Newberry said he followed the latter definition, and Professor Hicks the former, in agreement with which he had identified the Nebraska deposits. Mr. Claypole referred to Heilprin's recent identification of certain so-called Permian beds in the Wyoming valley of Pennsylvania as true Upper coal measures, and Professor H. S. Williams closed the discussion by noting that the beaks of certain shells (Streptorhynchus) in the Nebraska collection were not enough twisted to be considered Permian. Professor Hicks then described diagrams of sections found in typical deep-well sections, and exhibited a map of the salt-basins near Lincoln; the streams flowing from some of the basins are made strongly saline.

Cambrian in New York.—Mr. C. D. WALCOTT briefly announced the discovery of fossils showing the Cambrian age of the roofing-slates of Granville, Washington Co., N. Y.

Cretaceous Flora, Devonian and Carboniferous Fishes.—Professor NEWBERRY presented papers upon the U. S. Cretaceous flora and Devonian and Carboniferous fishes. The angiosperm plants of the Cretaceous were described as appearing suddenly in great variety and advanced development, and displacing the pre-existent flora; many forms were even then closely like trees still living, and certain flowers had been identified by Dr. Gray as Compositæ, though the author could not yet fully accept so surprising a determination.

In describing the fossil fishes, the remarkable discoveries of Hertzer and Terrell were recounted, and fine specimens and plates exhibited. Collections from eastern New York gave promise of a rich fauna in the Catskill formation, which was regarded as a fresh-water lake-deposit, much like the old red sandstone of Scotland in many features. The Pterichthys of this formation was compared with existing Siluroid fishes from South America, partly because of similar markings where the arm was joined to the body. Professor Cope thought that too little was known of these ancient forms to attempt to trace such relationships, and thought that the correspondence in markings might be homoplastic, the result of development under similar conditions, and not homogenetic, or inherited from a common stock.

Recession of Niagara River.—In the Niagara discussion Mr. WOODWARD gave the following numerical results:

Points located.	State Survey, 1842.	Lake Survey, 1875.	Geological Survey, 1886.
Horseshoe fall,	12	16	30
American fall,	18	15	24

Twenty-three hundred feet is the length of the front of the Horseshoe fall, to which the following numbers relate:

Interval.	Area worn away.	Mean annual recession.
1842–1875	4·25 acres.	2·44 feet.
1842–1886	5·62	2·42
1875–1886	1·37	2·38

The fastest recession is at the center of the fall, where a projection marked on the Lake Survey map has been converted into a strong recession, the distance of retreat here being from 200 to 275 feet in eleven years.

Mr. G. K. GILBERT's study of the place of Niagara in geologic history was in one sense a continuation of his account of the tilted shore lines of old Ontario, presented at Ann Arbor a year ago. A shore line is found south of Buffalo, about two hundred feet above Lake Erie, and has been traced eastward as far as Alden, on a branch of the Erie Railway; the water from this high level probably draining into the Ohio by some outlet not yet well defined, until the retreat of the ice in eastern New York allowed it to escape by the Mohawk. The change from the upper to the lower level was sudden, as no shore lines are known at intermediate altitudes; and this change allowed Erie to drain into Ontario by the Niagara River. The conditions that might cause a variation from the present rate of retreat of the falls were then discussed, reaching the conclusion that the present rate is a minimum, and consequently that the surprisingly low maximum of 7,000 years is all that can be allowed for the excavation of the gorge. This paper was illustrated by maps and sections that placed its meaning immediately before the audience.

The subject was further discussed by Messrs. Claypole, Davis, Comstock and Holley. The first speaker compared Buffalo and Chicago, illustrating a "geological might-have-been" in the contrast between their relation to the outlet of the Great Lakes, which was determined by slight differences of altitude. The second alluded to the contrast in form between the relatively wide-open and mature old valley, filled with drift from the whirlpool to St. David's, and the narrow, steep-sided immature gorge of the Niagara. Mr. Comstock discussed the influence of joints in the limestone on the direction of the gorge, and Mr. Holley referred to circumstances in the thickness and altitude of the rocks which he thought made seven thousand years too short a time for the recession of the falls.

Topography of Chesapeake Bay.—A paper full of significant detail was presented by W. H. MCGEE on the geography and topography of the head of Chesapeake bay, in which the form of the water-courses was used as a guide to the history of the region. The "fall-line," separating the rougher piedmont region from the smoother coastal plain, was shown to divide also systems of streams of strongly different characteristics; on the first the streams follow valleys well elevated above tide level, and reach the bay over falls; on the second, the streams, many of which run obliquely westward toward the bay, follow partly submerged valleys as they enter it: the geological explanation of these facts was unhappily crowded out for lack of time.

Holyoke trap range.—Almost the only approach to petrographical investigation appeared in the paper by B. K. EMERSON of Amherst, on the Holyoke trap range, whose structure and composition were worked out with much success. The main trap sheet was recognized as of contemporaneous overflow origin, and consists of monotonous diabase, with alteration throughout: on the other hand, certain necks or plugs of lava, seen breaking across the sandstones, and of roughly circular area, are found to be unchanged by alteration, and to possess a very glassy base. Evidence was found in the steep faces of some fault bluffs for the recent occurrence of dislocation in this region.

Bernardston Devonian, in the Connecticut valley.—Professor Emerson also showed a map of the Bernardston Devonian limestone district in northern Massachusetts, in which the distribution and attitude of the rocks were displayed with much detail.

Origin of the Pottsville and other Conglomerates.—The origin of wide-spread and heavy conglomerates, such as the Pottsville, was discussed by Mr. BRANNER, who preferred to explain them by the action of tidal bores, such as occur on the Amazon. He pointed out that in favorable conditions, the bore may have an extended development and not be limited only to the mouth of a river. Dr. Comstock supported him in this view. Mr. Davis pointed out the need of a strong transporting agent in the origin of conglomerates that consist of materials unlike the rocks on which they lie, but on account of the local nature of the tidal bore looked rather to general stronger tides for the needed agent, and Mr. Claypole took similar ground. Mr. Merrill showed that not only the transportation but the origin of certain gravels in New Jersey awaited explanation.

Distortion of Cretaceous and Tertiary beds on Long Island and the islands east of it.—In illustration of some dynamic effects of the ice sheet, Mr. F. J. H. Merrill of New York described the distortion of certain Cretaceous and Tertiary beds on Long Island and southern New England, including those of Gay and Sankaty Heads. Many morainic ridges were found to owe their height in good part to anticlinal deformation of the beds below them by glacial thrust; stratified deposits containing post-Pliocene shells were thought to be older than the Champlain epoch, and their present altitude was regarded as the result rather of local glacial disturbance than of continental elevation.

Recent geological anticlinals.—"An account of some new geologic wrinkles" served Mr. Gilbert as an introduction for an ingenious hypothesis. He has lately discovered several small post-glacial anticlinals in the horizontal limestones of Jefferson Co., N. Y. and in the shales near Dunkirk, in the western part of the State, and suggests that they may have resulted from expansion caused by the warming up of the surface layers of the rocks as they recovered from the cold of the Glacial period.

The titles of all the papers accepted for reading in the Geological Section are given on pages 330 and 331.

2. *Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey;* by ROBERT P. WHITFIELD. Vol. I. 270 pp. 4to, with 35 lithographic plates of fossils and a colored geological map of part of the State. Geological Sur-

vey of New Jersey. Trenton, 1886.—This very valuable Report contains descriptions, synonymy and figures of all the described species of brachiopods and lamellibranchs in the formations mentioned, together with some that are new. The total number, exclusive of the brachiopods (5), is 230. Of these, 5 are from the Raritan clays below the Lower Marl beds, 163 from the Lower Marls, 11 in the Middle Marl bed, 17 in the Cretaceous layer at the base of the Upper Marl bed which is Eocene, 23 from the top of the Upper Marl bed, and 12, species of Unionidæ, from the clays at Fish House. Only one species of the 163 in the Lower marl, *Gryphæa vesicularis*, is found in any of the other beds; this species occurs also in the Middle Marl bed, besides which a single individual has been found in the Eocene. "Very few of the species have been recognized from localities outside of the State." Of Brachiopoda, the only genera reported are *Terebratula, Terebratulina* and *Terebratella. Terebratella plicata* is common in the Gryphæa beds of the Lower Marls, while *Terebratula Harlani* is in great abundance, in some places almost wholly constituting beds several feet in thickness. The other species are rare.

The five species of Lamellibranchs from the Raritan clays, referred to the genera *Astarte, Ambonicardia* (new), *Corbicula* and *Gnathodon*, have in part a Jurassic aspect, but the conformably overlying beds all contain unquestionably Cretaceous fossils, as Professor Cook states in his prefatory remarks.

The plates of the volume are excellent. Mr. Whitfield has a second volume in progress, devoted to the Gasteropoda and Cephalopoda of the same formations, which will soon go to press.

3. *Note on the recently proposed genus Billingsia;* by S. W. Ford.—Mr. J. F. Whiteaves having kindly brought to my notice the fact that the above generic name, proposed by me on page 466 of this Journal for June last, was bestowed by M. De Koninck, in 1876, upon a genus of compound corals from the Devonian rocks of Australia, I propose to substitute for it the name Elkania, based upon Mr. Billings' Christian name, Elkanah.

4. *A Catalogue of Minerals, alphabetically arranged, with their Chemical Composition and Synonyms;* by Albert H. Chester. 52 pp. 8vo. New York, 1886 (John Wiley & Sons).—This is a handsomely printed list of the mineral names now in use, including synonyms and names of varieties; after the name of each species a general statement of the chemical composition is given. Collectors will find this catalogue useful.

5. Hooker's *Flora of British India*, Part xiii, just now issued, commences the fifth volume, and carries it on to p. 240. It comprises the *Chenopodiaceæ, Polygonaceæ, Podostemonaceæ, Nepenthaceæ, Cytinaceæ, Aristolochiaceæ, Piperaceæ, Chloranthaceæ, Myristicaceæ* (30 species of *Myristica*), *Monimiaceæ, Laurineæ* (16 genera, one of them of 64 species), *Proteaceæ, Thymeleaceæ, Elæagnaceæ, Loranthaceæ* (with 58 species of *Loranthus*), *Santalaceæ, Balanophoreæ,* and the opening pages of *Euphorbiaceæ;* all by Sir Joseph Hooker himself, who, relieved

of official cares, is thus putting forward this great work with renewed vigor and advantage. A. G.

6. *Notice Biographique sur Alphonse Lavallée;* par M. HENRY L. DE VILMORIN. pp. 46, 8vo.—A very interesting account of a very interesting man and of his work, so suddenly and sadly cut short. It is an address to the National Agricultural Society of France, of which Lavallée was a leading member and an officer. A. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Astronomical Journal.*—In a printed circular Dr. Gould announces his desire to re-establish the Astronomical Journal, which was suspended at the close of its sixth volume, shortly after the beginning of the war. He proposes to carry out the plan as soon as a sufficient number of subscriptions has been received to meet half the estimated expenses.

The Astronomical Journal is to be devoted to the advancement, rather than the diffusion, of knowledge, and its numbers will be issued at irregular intervals, although it is hoped to complete a volume annually. The price is $5.00 for the volume of twenty-four numbers, with table of contents and index.

Those disposed to subscribe are requested to notify him at Cambridge, Mass., as early as may be convenient. The Journal should have great success.

2. *The Moon's Surface.*—Captain JOHN ERICSSON has, in *Nature* of July 15th (p. 248), a paper well worked out, aiming to prove that the rims of the great craters of the moon are made of ice, through the freezing by the intense cold of the surface, of vapors of water rising from the pits. He alludes to a paper of his read before the American Academy of Sciences in 1869, in which he dissented from Herschel's view that the heat of the moon on the side toward the sun exceeded that of boiling water, and said that "nothing but the assumption of extreme cold offers a satisfactory explanation of the absence of any gaseous envelope round a planetary body, which, on account of its near proximity cannot vary much from the earth as regards its composition." In the following number of *Nature,* Mr. G. H. Darwin states, in a brief note, that in May, 1884, Mr. Peal, of Silbsagar, in Assam, who has studied the moon's surface with great attention, sent him a paper in which he maintained views closely resembling those of Captain Ericsson; to whom he replied suggesting that "it was difficult to admit the existence of ice on the moon's surface without a layer of water vapor over it, and that the telescope proves that if such vapor exists it is only in exceedingly small quantities." Mr. Darwin presents the note simply to draw attention to the correspondence, not saying that he holds still the opinion he then expressed.

3. *American Association for the Advancement of Science.*—The thirty-fifth meeting of the Association opened at Buffalo

on the 18th of August, under Professor Edward S. Morse, of Salem, as the President. The evening of the same day the retiring President, Professor H. A. Newton, delivered his address, giving a lucid popular exposition of the subject of Meteorites, Meteors and Shooting Stars. The Sections were opened by addresses of the Vice-Presidents: Professor Willard Gibbs, of New Haven, of the Mathematical Section, on Multiple Algebra; Professor C. F. Brackett, of Princeton, of the Physical Section, on the Electromotive Force of the Voltaic Cell; Professor H. C. Wiley, of Washington, of the Chemical Section, on the Economic aspects of Agricultural Chemistry; Professor T. C. Chamberlin, of Beloit, of the Geological Section, on the Glacial Drift; Mr. H. P. Bowditch, of Boston, of the Biological Section, on Nerve Force; Mr. O. Chanute, of Kansas City, of the Section on Mechanical Science and Engineering, on Scientific Invention; Mr. Horatio Hale, of the Anthropological Section, on the Origin of Languages; Mr. Joseph Cummings, of Evanston, of the Section of Economic Science and Statistics, on Capitalists and Laborers. A list of the papers accepted for reading is given below.

Saturday was given up to excursions, for which the citizens of Buffalo had made liberal provision. Members of the Geological section availed themselves of the opportunity for an exploration of the Niagara gorge; and the forenoon of the following Monday was occupied by them in a discussion of the subject with special reference to its chronological bearings, in which Professor G. K. Gilbert, Dr. Pohlman, Professor E. W. Claypole, Professor Chamberlin, Professor W. M. Davis, and others took part.

Professor S. P. LANGLEY was elected President for the next meeting of the Association. The Vice-Presidents appointed are: WM. FERREL, of Washington, for the section of Mathematics; and Astronomy; WM. A. ANTHONY, of Ithaca, that of Physics A. B. PRESCOTT, of Ann Arbor, that of Chemistry; E. B. COXE, of Drifton, Pa., that of Mechanical Science and Engineering; G. K. GILBERT, of Washington, that of Geology and Geography; W. G. FARLOW, of Cambridge, that of Biology; D. G. BRINTON, of Media, Pa., that of Anthropology; and H. E. ALVORD, of Amherst, Mass., that of Economic Science and Statistics. The place of meeting in 1887 was left to be decided by the Standing Committee.

List of Papers accepted for Reading.

SECTION A.—*Mathematics and Astronomy.*

J. BURKITT WEBB: Second differentials and equicrescent variables.

THOMAS HILL: Hirundo—a new curve.

WM. A. ROGERS: On the degree of accuracy which may be expected from chronograph records. On a method of determining the constants of precession which is partially independent of the variations of the proper motion of the stars employed.

WM. A. ROGERS and ANNA WINLOCK: On the limitations in the use of Taylor's theorem for the computation of the precessions of close polar stars.

Henry Farquhar: Comparison of the Boss and Auwers declination-standards.

D. P. Todd: On some mechanical attachments (partly novel and partly not) for facilitating the astronomer's work with the equatorial.

C. L. Doolittle: Change in the latitude of the Sayre Observatory.

H. B. Fine: A new demonstration of Cayley's Theorem on the intersections of curves. Any point or plane (tangential) singularity in an element of a curve of double curvature can be completely defined by aid of three singularity indices K_1, K_2, K_3.

B. A. Gould: Photographic determinations of stellar position.

E. F. Sawyer: Some account of a new catalogue of the magnitude of southern stars.

Chas. K. Wead: On certain indeterminate and discontinuous functions with some applications.

S. C. Chandler, Jr.: A comparative estimate of methods and results in stellar photometry. On the use of the zenith telescope for latitude.

W. L. Elkin: Comparison of the places of the Pleiades as determined by the Königsberg and Yale College heliometers.

C. M. Woodward: Some of the properties of the Torus. A note on the equations of tangents to plane curves.

Cleveland Abbe: A neglected correction in the use of refraction tables.

Henry M. Parkhurst: Magnifying power of telescopes.

E. E. Barnard: Telescopic observations of meteor trains.

John H. Kedzie: A new theory of gravitation.

John Haywood: Apparatus: An instrument to show at any time the direction of the earth in space, in its annual motion.

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Errata for the August Number.

Page 129, line 15 from bottom, for millimeters read centimeters.
Page 132, line 17 from top, for four hundred times read forty times.

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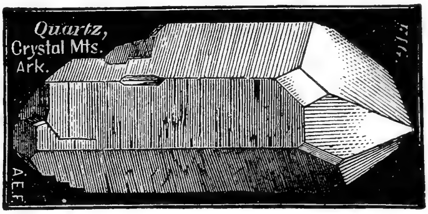

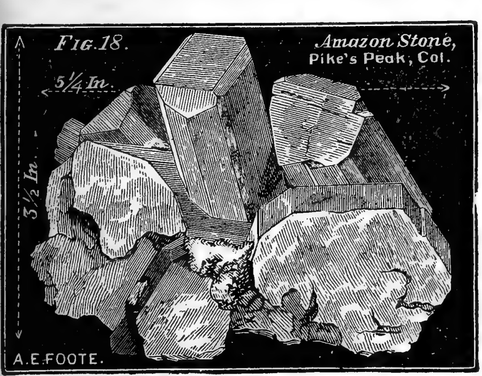

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. XXXVIII.—*The Higher Oxides of Copper;* by Thomas B. Osborne.

Copper dioxide.—When copper hydroxide is treated with hydrogen dioxide at a temperature near 0° C. a brown precipitate is formed which has been shown to contain nearly twice as much oxygen as copper oxide (CuO) and when acidified yields hydrogen dioxide. When the temperature is somewhat higher a grass-green precipitate is formed which is sometimes yellow-green or yellow. Krüss (Berichte, 2593, 1884) has shown that the brown precipitate, when treated at 0° C. for some days with excess of hydrogen dioxide and frequently shaken, can be filtered and washed first with alcohol and then with ether and when entirely freed from water can be dried at 100° C. It then has the composition of CuO_2, H_2O or H_2CuO_3. When moist Krüss found that it began to decompose above +6° C. Above this temperature he obtained a grass-green precipitate which began to decompose above +12° C. He was unable to analyze this latter as it decomposed readily.

Brodie has shown that if hydrogen dioxide be added to a salt of copper in solution and then soda, a yellow precipitate is formed.

Krüss obtained a yellow precipitate in too small quantity to analyze, by fusing copper oxide with sodium chloride with access of air. He thought this was a higher oxide of copper and anhydrous, and suggested that it might be the same as Brodie's oxide. Having been unable to find any investigations of the composition of these variously colored precipitates I thought it worth while to try and straighten them out. I found that if copper hydroxide (prepared by precipitating nitrate of copper with soda and washing thoroughly with cold water by decantation so as to keep the copper hydroxide in a state of the finest possible subdivision) was treated with hydrogen dioxide in small amounts, a green precipitate was formed which by further action of hydrogen dioxide was changed into a brown. This brown precipitate was yellow by transmitted light but dark brown by reflected light. When a small amount was shaken up with water it appeared yellow. I found that by mixing increasing amounts of hydrogen dioxide with copper hydroxide the color of the precipitate varied from a yellow with a greenish tinge, through yellow to brown. I made a number of preparations thus varying in color and after washing by decantation free from hydrogen dioxide determined the hydrogen dioxide set free by dissolving the precipitate, suspended in water, with dilute sulphuric acid. By using a solution of potassium permanganate of known strength the hydrogen dioxide set free was easily determined, the copper in the solution was precipitated with hydrogen sulphide and determined, and the ratio between the excess of oxygen found by titration, and the copper oxide calculated. In this way I found the following ratio between the oxide of copper and the oxygen for the different colored precipitates with the exception of I, which was determined by filtering and washing the precipitate with water, alcohol and ether, cooled to 0° C., drying at 100° C. and then heating in a tube in a current of dry air, weighing the water and copper oxide and calculating the oxygen by difference.

		Per cent.	Weight.	Ratio.
I. Grass green	CuO	82·35	·6679	12·2
	H_2O	16·29	·1322	
	O	1·36	·0110	1·
		100·00		
II. Grass green	CuO		·2717	12·7
	O		·00422	1·
III. Yellow green	CuO		·3040	7·5
	O		·00814	1·
IV. Yellower green	CuO		·0701	5·14
	O		·00275	1·
V. Yellow (green tinge)	CuO		·4757	4·2
	O		·02271	1·
VI. Yellow	CuO		·0633	3·1
	O		·00413	1·

VII.	Yellow brown	CuO	·2018	1·66
		O	·02457	1·
VIII.	Brown (yellow tinge)	CuO	·2847	1·48
		O	·03893	1·
IX.	Brown	CuO	·2813	1·2
		O	·04669	1·

From these analyses I concluded that the green precipitates were simply mixtures of the yellow with the blue and that the yellow was a mixture of the brown and the green, the reddish brown color of the dioxide of copper being complementary to the green and thus destroying one another and leaving the yellow predominant. That these different colors are mixtures of CuO_2, H_2O and $Cu(OH)_2$ was further supported by the fact that I could reproduce any shade of color by mixing at any temperature the brown CuO_2, H_2O with $Cu(OH)_2$ in proper proportions. Furthermore the fact that all yielded hydrogen dioxide when dissolved in dilute acids without evolution of oxygen is evidence in support of this view.

I found further that I could filter, wash and dry these precipitates under the same conditions that Krüss employed for CuO_2, H_2O; and analysis by heating in a tube and weighing the water and copper oxide gave results similar to those obtained by determining the hydrogen dioxide set free by acids, as is seen by I which was determined in this way while II was obtained by the permanganate method. I did not find that any of these precipitates decomposed at low temperatures when free from hydrogen dioxide. Krüss states that the brown precipitates begin to decompose above +6° C. and the green above +12° C. I found that when hydrogen dioxide was present there was a slow evolution of oxygen even below +5° C. which increased as the temperature rose. The precipitate however underwent no apparent change until boiled for a moment or two, when it suddenly yielded a large amount of oxygen and black CuO separated out. It would appear then that the decomposition below 100° C. is of the hydrogen dioxide, brought about by the action of the copper dioxide.

From the fact that no definite composition can be assigned to any of these various colored precipitates except the blue copper hydroxide and the brown copper dioxide, that they all yield hydrogen dioxide with acids, that they show the same behavior on heating, that the different colors can be produced by different amounts of hydrogen dioxide with the same amount of copper hydroxide and that the colors may be reproduced by mixing the copper hydroxide and the copper dioxide, it seems reasonable to conclude that hydrogen dioxide forms but one higher oxide with copper.

Further the yellow oxide obtained by Krüss by fusing copperoxide with sodium chloride cannot be the same as Brodie's as suggested by Krüss, for the latter's compound must have been anhydrous while Brodie's is most probably a mixture of copper hydroxide with copper dioxide. When boiling a small amount of copper dioxide with water I obtained after a few minutes a bright yellow precipitate which did not decompose even when boiled for sometime, nor on standing some days in a test tube in the laboratory. There was too little to analyze and I could not obtain it again. This may have been the same oxide as Krüss obtained by fusing copper oxide with sodium chloride. Lack of time prevented me from further investigating this compound.

Copper sesquioxide.—Crum (Liebig's Annalen, lv, p. 213) described a higher oxide of copper which he obtained by mixing with one pound of bleaching powder, solution sp. gr. 1·06, 50 grains sifted calcium hydroxide, and then adding to the solution cooled to 0° C. 20 grains of copper oxide dissolved in 70 grains of nitric acid sp. gr. 1·3. In this way he obtained a blue solution from which a black precipitate separated on standing some hours. This precipitate evolved oxygen and floated on the top of the solution for sometime. After twenty-four hours or more the oxygen ceased to come off and the precipitate settled to the bottom in a dense condition. This precipitate, when finely divided, had a crimson tinge and a brighter red color when rubbed with a rod to a thin layer on glass. When soda was used instead of the suspended lime, he obtained a rose-red precipitate which would not settle. Crum considered the precipitate obtained with lime the same as that obtained with soda and attributed the difference in color to a difference in subdivision. He succeeded in washing the dense black precipitate by decanting with cold lime water and found that it contained no Cl and an excess of oxygen.

He made several determinations of the ratio between the copper and the oxygen by taking a weighed amount of copper oxide, treating it as described and measuring the amount of oxygen evolved on acidifying. For 20 grains of copper oxide he obtains in six analyses, I 1·875, II 1·886, III 1·748, IV 1·915, V 1·795, VI 1·747 grains of oxygen. The mean is 1·828 grains. Cu_2O_3 would require 1·98 grains. By re-calculating these results so as to show the ratio between the oxygen found and the copper oxide I obtained the following numbers:

I. For one atom of oxygen, 2·14 copper oxide.
II. " " " 2·15 "
III. " " " 2·30 "
IV. " " " 2·11 "
V. " " " 2·24 "
VI. " " " 2·30 "

From this he concluded that the formula of the oxide was probably Cu_2O_3 and further that this oxide acted as an acid and was united with lime, forming a cuprate of calcium, although he obtained no proof that this latter supposition was correct. I repeated Crum's experiments in making this compound of copper with the results as described by him. Hoping to obtain a more accurate determination of the oxygen I tried the following method.

After the precipitate had settled, the hypochlorite solution was poured off as far as possible and then the flask filled up with lime water and shaken in order to mix thoroughly. After allowing the precipitate to completely settle, 50 c. c. of the clear solution were drawn off and a known amount of ferrous sulphate solution run in and after standing some minutes sulphuric acid added to dissolve the precipitated ferrous and ferric hydroxides and then the excess of ferrous sulphate titrated off. 50 c. c. of the solution containing the copper precipitate were next drawn from the bottom of the flask and treated with the same amount of ferrous sulphate solution in the same way. The difference in the titer in the two cases represented the oxidation due to the excess of oxygen in the copper compound. The strength of the permanganate solution being known the weight of oxygen was easily calculated. The first 50 c. c. of clear solution drawn off were in all cases examined for copper but none was found. The copper in the other 50 c. c. was carefully determined and the ratio between the copper oxide found and the excess of oxygen calculated. Thus I obtained the following results:

A.

	Weight.	Ratio.
I.	CuO = ·1888 grams.	CuO = 2·95
	O = ·0129 “	O = 1·
II.	CuO = ·1261 “	CuO = 3·
	O = ·0084 “	O = 1·
III.	CuO = ·0861 “	CuO = 3·25
	O = ·0053 “	O = 1·

B.

		Washed thoroughly by decantation.
I.	CuO = ·1524 “	CuO = 2·38
	O = ·0129 “	O = 1·
II.	CuO = ·3182 “	CuO = 2·57
	O = ·0249 “	O = 1·

C.

I.	CuO = ·2278 “	CuO = 2·83
	O = ·0162 “	O = 1·
II.	CuO = ·0716 “	CuO = 2·40
	O = ·0060 “	O = 1·

III.	CuO = ·1505 grams.	CuO = 2·25
	O = ·0135 "	O = 1·
IV.	CuO = ·1217 "	CuO = 2·7
	O = ·0092 "	O = 1·

D.

Ferrous chloride was substituted for ferrous sulphate with results as follows :

	Weight.	Ratio.
I.	CuO = ·1687 grams.	CuO = 2·93
	O = ·0117 "	O = 1·
II.	CuO = ·1614 "	CuO = 2·90
	O = ·0113 "	O = 1·
III.	CuO = ·0703 "	CuO = 2·4
	O = ·0059 "	O = 1·

To what the irregularities in the results were due I am unable to say. The action of the hypochlorite solution on the ferrous sulphate solution was the same when equal quantities were used. No hydrogen dioxide could be found in the acidified solutions which could act on the iron irregularly and also on the permanganate, and no oxygen escaped on acidifying. I think it probable that a more extended trial of this method would yield satisfactory results.

I tried to use potassium iodide instead of ferrous sulphate but with little promise of success as the results varied greatly. I found it exceedingly difficult to obtain constant results with potassium iodide in determining cupric salts alone except in very dilute solutions so I abandoned this method as unreliable.

Of course it would be impossible to prove whether calcium was a constituent of this copper precipitate or not when made according to Crum's method, for the suspended calcium hydroxide settles down with the precipitate containing copper and could not be separated. I found, however, that a large excess of lime water could be substituted for the suspended calcium hydroxide. By filtering the cold calcium hypochlorite solution carefully into a large flask provided with a rubber stopper, with two holes, through one of which the funnel passed and through the other a tube filled with broken stick potash to exclude carbonic acid, and then running in about one liter of cold lime water, and adding the copper nitrate solution, the copper hydroxide which first precipitated, in four or five minutes went into a perfectly clear solution of a deep blue color. This solution soon changed to a green and then became nearly black, and from this a precipitate began to separate which had a crimson color by transmitted light, and appeared exactly like the precipitate obtained with barium hypochlorite instead of calcium to be described beyond. In a few minutes this precipitate began to evolve oxygen and was converted into a heavy flocculent black precipitate.

Oxygen continued to be evolved for some hours and the precipitate was kept floating on the surface. After standing twenty-four hours on ice, it had settled. A portion of the solution containing this precipitate was drawn off and washed with lime water. Under the microscope this precipitate appeared perfectly homogeneous and with a decided pink tint. The oxygen was determined with ferrous sulphate in 50 c. c. of the solution containing the precipitate as before described, and likewise the copper and the calcium. 50 c. c. of the clear solution were drawn off and found to be free from copper and the calcium determined. By subtracting the calcium found in the solution from that found in the solution plus the precipitate, the calcium of the precipitate was found. The error due to the amount of the solution displaced by the precipitate was too small to make any serious difference in the results.

In this way I found

	In sol. + precipitate.	Solution alone.
CuO =	·1869 grams	none
CaO =	·1798	·1104 grams.
O =	·0108	none

	Weight.
CaO in p. p. + sol.	·1798
CaO in sol.	·1104
CaO in p. p.	·0694

Precipitate.	Weight.	Ratio.
CuO =	·1869 =	23·54
CaO =	·0694 =	12·39
O =	·0108 =	·0675

The oxygen found in this case is much lower than in the other analyses given, but from the wide variations in the former results its determination cannot be considered more than a qualitative test. The calcium it will be seen is in nearly a ratio of two atoms of copper to one of calcium, but I consider this single analysis by no means evidence of anything more than the *presence* of calcium in the compound and is so far as I can find the only direct evidence that copper ever acts as an acid.

The rest of the precipitate from which this sample was taken for analysis was allowed to stand a week packed in ice. It grew gradually more and more dense and of a brighter pink, until finally it was of a very brilliant rose red, and formed in places on the sides of the flask very thin layers of a dazzling crimson. In the hope of being able to analyze this as Krüss did the dioxide of copper, I arranged a filter packed in ice and covered with a bell jar communicating with the air through potash tubes, so as to keep out all carbonic acid, but before I could wash the precipitate it began to turn blue next to the paper. The middle portions were dried in the cold over sulphuric acid and remained quite pink when dry, but the decom position had extended so far, I abandoned the analysis intending to try again, but have not since had time. Unfortunately lack of time prevented me from working further in this direction, and I give my results in hope that they may be of service to others in following up this subject and settling beyond a doubt the composition of this interesting compound.

When barium hypochlorite in alkaline solutions is allowed to act on copper salts in the cold, a crimson red precipitate is formed, which somewhat resembles the calcium cuprate just described, but in many respects appears different. But little seems to be known of this compound, it having been supposed to be either a higher oxide of copper, the same as the precipitate obtained with calcium, or else a corresponding barium salt. In hope of being able to analyze this red precipitate, I obtained results which I am entirely unable to account for and publish them in the hope that some one may be tempted to investigate further and reach a satisfactory conclusion.

In order to make the red precipitate I found it best to put about 50 c. c. of strong baryta water cooled to about 5° C. in a small flask, add ·2 gram of copper as nitrate or chloride, and then to pass chlorine gas through the solution till the color changed to a blackish green, then to add 100 c. c. of baryta water of 5° C., and after shaking vigorously let stand about half an hour. The precipitate which forms on adding the 100 c. c. of baryta water changes from a blackish green to a dark dirty red and then slowly to a bright crimson. This precipitate settles very slowly and evolves a gas gradually, and even when kept cold will decompose on standing a few hours. All my attempts to wash it failed utterly. On a filter paper it decomposed rapidly. When washed with cold baryta water by decantation, no apparent change beyond the very slow evolution of gas could be seen until several times decanted, when suddenly the crimson color would disappear and a dirty pinkish precipitate remain. I had to abandon my attempts at decanting more than once or twice and endeavored to determine the composition of the precipitate by decanting once, letting the precipitate settle, and then drawing off 50 c. c. of the clear solution and 50 c. c. of the solution containing the precipitate and analyzing each, the difference representing the precipitate.

No. 1.

		Precip. + sol.	Sol.		Diff. = p. p.
I. CuO	=	·2905	----	=	·2905
BaO		·6965	·6669		·0296
O		·0269	·0267		·0002
Cl		·0268	·0245		·0023
II. CuO		·3422	----		·3422
BaO		·7025	·6657		·0368

No. 2.

I.	CuO	·3035	----	·3035
	BaO	1·0754	1·0222	·0532
	O	·0242	·0240	·0002
II.	CuO	·3127	----	·3127
	BaO	1·0837	1·0197	·0640

No. 3.

I.	CuO	·2603	----	·2603
	BaO	·5698	·5577	·0121
	O	·0082	·0072	·0010
	Cl	·0142	·0118	·0024
II.	CuO	·1918	----	·1918
	BaO	·5627	·5577	·0050
	O	·0082	·0064	·0018

The above analyses show a small amount of barium in the precipitates, compared with the copper, which varies greatly with the different preparations and considerably in the different samples of the same preparation, while duplicate determinations in the solutions agree quite closely. A little chlorine was also present, but it seems more probable that the barium and chlorine were carried down with the precipitate as barium chloride than that they were united with the copper. The results show a fair average of a very large number of determinations of oxygen in various preparations. While with the calcium-copper precipitates I never failed to get an oxidation of the ferrous sulphate or chloride, with the barium-copper precipitates I never got an oxidation greater than in No. 3, II. It is evident that we have here two different compounds, but what the barium precipitate can be I cannot even suggest. I could get no evidence of an excess of oxygen in it in any way. Iodized starch paper was unchanged when placed near the precipitate moistened with hydrochloric acid; whereas chlorine was freely evolved when the calcium cuprate was thus treated. When treated with sulphuric acid there was no evolution of oxygen, while with the calcium cuprate there was always a lively evolution of gas. When strontium was substituted for barium the same changes of color took place, excepting a darker, duller red precipitate was formed. It was necessary to suspend finely ground crystals of strontium hydroxide in the water on account of its slight solubility.

With barium, strontium and calcium (when calcium hydroxide solution is used instead of suspended lime) the same changes of color take place, but in the case of the calcium the red precipitate, which is the final state with the barium and strontium precipitates, is followed by a change to a bulky black precipitate which evolves oxygen for some time and gradually settles in the solution and changes to a crystalline rose-red precipitate.

The probability of my being unable to continue this investigation, for some time at least, has induced me to publish these very incomplete results in the hope that the beginning I have made will be of use to others who may wish to follow this subject further.

Sheffield Laboratory, April 10, 1886.

ART. XXXIX.—*The structure of the Triassic formation of the Connecticut Valley;* by WILLIAM MORRIS DAVIS.

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CONTENTS: The physical problem—Limitation of acceptable hypothesis—Disturbance has taken place—Its date is after the period of deposition—It was not caused by overflow or intrusion of trap-sheets—It was not a simple monoclinal tilting—Evidence for occurrence of unseen faults—Their systematic position—Their control of the topography—Crescentic ridges—Area and depth of disturbance—Probable character of disturbing force—Its action on the fundamental schists—Consequent monoclinal faulting of overlying Triassic strata—Strike of faults determined by strike of schists.

THE trap-ridges in several parts of the Triassic formation of the Connecticut Valley were examined in the summer of 1885, with the aid of Mr. C. L. Whittle, volunteer assistant, and the results obtained fully confirm the suggestion made several years ago (this Journal, 1882, xxiv, 345; Bull. Museum Comp. Zool., vii, 1883, 249; Proc. Boston Soc. Nat. Hist. xxii, 1882, 116), to the effect that nearly all these ridges are the outcropping edges of contemporaneous lava overflows, and that the outcrop of a single sheet is repeated several times by faults nearly parallel to the strike of the beds. The evidence on which these conclusions rest will be presented more fully in the Seventh Annual Report, U. S. Geological Survey. The only considerable ridges formed by intrusive trap sheets seem to be those in the lower part of the formation included in Percival's western group; but these have not yet been sufficiently examined to make it clear that they are all of this origin.

On the basis of these results, it is desired to present here in brief form an hypothesis that may account for the peculiar eastward monoclinal structure of the formation. It will be best understood by approaching it through a review of the suggestions that have heretofore been made to the same end.

It was early suggested* that the monoclinal attitude of the formation might result from original oblique deposition or cross-bedding on a large scale. Apart from the improbability of

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* H. D. Rogers, Third Ann. Rep. Geol. Surv. Pa., 1839; Geol. New Jersey, 1840, 166.

so wholesale a process, it is excluded first by the occurrence of coarse conglomerates on the eastern margin of the formation where they dip strongly toward the ledges of crystalline rocks from which they were doubtless derived, and from which they are now separated by a well-proved fault, with heavy downthrow on the western side; second by the numerous faults in the middle area of the formation, whereby the trap-ridges are so systematically repeated. Whatever hypothesis be accepted in explanation of the monoclinal attitude, its first requisite is for these reasons that the strata have actually been disturbed since their deposition.

It has been more recently proposed* to account for the Triassic monoclinal in New Jersey, which in so many ways resembles that of the Connecticut Valley, by a progressive disturbance during the deposit of the strata. The mechanical difficulties in the way of this process are to my mind rather formidable, but independently of these, it cannot be accepted for the Connecticut Valley, because it does not account for the occurrence of faults that here form so characteristic a part of the structure and that are so essentially connected with the rest of the deformation. Moreover, before the faulting the strata now disjointed must have been continuous; and the nearly uniform thickness over large areas of the trap overflows that are buried between the sedimentary beds shows that they at least could not then have been inclined at their present dip, but that the whole series must have lain essentially horizontal. Finally, the displacement of the highest as well as of the lowest members of the series by the faults, and probably in some cases by the same fault, indicates that these dislocations did not begin till after the whole formation was practically completed; or to put it in a more natural form, this indicates that the period of deposition continued until it was closed by the elevation accompanying the disturbances that have given rise to the existing structure. It is probable, on the other hand, that certain uneven changes of level took place during the accumulation of the strata, for they are of considerable thickness on a rather limited area, they present many marks of shallow water during their deposition, and extended eruptive action characterized the latter part of the period; but these changes may practically be neglected in seeking for an explanation of the existing structure. The second requisite of an acceptable hypothesis is therefore that it should recognize the original horizontal position of the beds, and place their disturbance after the accumulation ended.

The occurrence of igneous rocks so closely associated with the Triassic formation, not only in the Connecticut Valley but

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*Cook, Geology of New Jersey, 1868, 174.

in its several other areas, where the monoclinal structure is also developed, early gave rise to the theory that the intrusion of these rocks must have caused the tilting of the adjoining beds. Whatever possibilities of disturbance such intrusions may possess, their action is certainly excluded from the greater part of the Connecticut Valley area, for here nearly all the igneous rocks are found to be contemporaneous overflows: the intrusive sheets form much the smaller share of the trap-ridges and seem to be limited to the western border of the formation. The overflows having taken their present position among the strata while the formation still lay horizontal, could have had no active share in disturbing it, but must instead have passively suffered deformation with it. It is very probable that the intrusive sheets also took their present position in the sedimentary series before the formation was tilted and faulted. Similar intrusive sheets are known among strata that still lie horizontal, and that were no more disturbed at the time of intrusion than was necessary to give place to the lavas that were driven between them. No peculiarity of structure is found in the neighborhood of these Triassic intrusions that is not found elsewhere in the formation; but on the contrary the structure that they and their adjoining sandstones present is a remarkably faithful imitation of the structure that is at once so peculiar and so characteristic in the overflow sheets in other parts of the formation; and even if the disturbance in the neighborhood of the intrusions be attributed to their action, this singular imitation remains to be accounted for. Indeed there is not only an imitation but a correlation in the structure of the districts occupied by the intrusions and overflows: the ridges formed on their outcropping edges are all convex to the west; where they are disjointed, their ends overlap or offset in a similar fashion; the overlaps or offsets of the West Rock range being in what Percival called the advancing order (south end of northern member overlapping north end of southern member on the west), like the Hanging Hills and other southern overflow ridges; while the Barn-door Hills in Granby, which seem to be the northern representative of the West Rock range, overlap in receding order, like the northern half of the great range that extends from the Hanging Hills to Mounts Tom and Holyoke. In view of this, it can hardly be doubted that the intrusive sheets as well as the overflows and bedded rocks once lay horizontal, and that the whole mass of strata, igneous as well as aqueous, was subsequently and passively deformed by an external disturbing force.

The idea that the whole monoclinal represents an unfaulted mass, tilted to an almost constant eastward dip,* has not gen-

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* This is most definitely presented in LeConte's Elements of Geology, 1878, 441.

erally found acceptance on account of the great thickness of strata that it involves. It implies indeed a disturbance of improbable simplicity, and is directly excluded by the presence of numerous strike faults, always with upthrow on the east, whereby single beds are enabled to do more than double duty, and a not immoderate thickness suffices to account for the breadth of the formation. Many of the smaller faults are almost directly visible: the evidence on which the existence of the larger ones rests is of the same character as that which is accepted to prove the occurrence of faults in such a region as Tennessee; namely, the repetition of corresponding series of beds. It is true that some members of the series here are sheets of trap; but when these sheets are found to be contemporaneous overflows, they at once take rank as conformable members of the formation, and gain a high value as indications of structure from the success with which they resist erosion and the prominence that their outcrops therefore maintain. To deny the existence of the larger faults requires one to admit the frequent recurrence of a definite complex sequence of formative conditions repeatedly causing the deposition of a series consisting of sandstone, amygdaloidal trap, limestone, shales, heavy trap, sandy shales, lighter trap and sandy shales, in this regular succession and of closely corresponding thickness, member for member. This is so inherently improbable that it would not be admitted for a moment, if the trap-sheets were sedimentary rocks, like the ridge-making sandstones of Tennessee; and it is difficult to see how the eruptive origin of the sheets lessens the improbability of the supposition. To admit the existence of the faults allows a natural explanation of these repeated sequences, reduces the otherwise surprising thickness of the formation to a moderate measure, and simplifies the eruptive action of the period by correlating nearly all the trap-ridges as the repeated outcrops of a very few overflow-sheets. If the fault-lines thus indicated were disorderly, and could not be shown to be related to one another, very complete evidence might be demanded in proof of them; but they are most systematic in their position. In any single district, they are all nearly parallel to one another; south of Hartford, their trend is north-northeast or northeast; north of Hartford, they follow closer to the meridian. The upthrow is on the east, with insignificant exception. It does not seem illegitimate to regard so systematic an arrangement as a valuable corroboration of the evidence that first indicated the existence of the faults, and even to use it as a means of extending their discovery to localities where the evidence from sequences could not be fully applied for want of sufficient outcrops. It has in this way been made at least extremely probable that all the large trap ridges from Talcott Mountain and the Hanging Hills to Toket and Pond Mountains near Long Island Sound are simply repeated outcrops of a single heavy sheet of trap, separated by faults; and that these faults and others belong to a system of fractures that divide the formation into a number of long, relatively narrow blocks, in every one of which the beds dip as a rule to the east at a moderate and tolerably constant angle.

The simple monoclinal also fails to explain the crescentic curvature of the trap ridges, that so early awakened interest. Their form cannot be attributed to the curvature of the fissures through which the trap was supplied, for the two finest examples, Pond and Toket Mountains are found to be overflow sheets, not intrusions; and the sedimentary beds below and above them are curved conformably with them. Among the observations that prove the contemporaneous origin of the trap, the following may be mentioned: the sandstone directly overlying the Toket Mountain trap-sheet contains many fragments of trap; and the cavities of its waterworn amygdaloidal surface are found neatly filled with fine, unbaked sediment. A very coarse conglomerate, containing numerous bowlders of trap, is closely associated with the posterior ridge of Pond Mountain. The two mountains must be regarded as the curved outcrops of gently folded or "dished" strata, cut off on the eastern side by faults. The crescentic form of the ridges is indeed closely correlated with the whole system of faults; for in several cases their curvature is increased by a succession of small dislocations on the hooks of the crescents. For example, the southern end of Pond Mountain, where crossed by the New Haven and Branford highroad and by the Shore Line Railroad, is notched by oblique faults, whose eastern upthrows materially add to the departure of the ridge from a straight line. Larger illustration of the same structure is seen in the dislocated members of the Hanging Hills by Meriden, and of the Mount Holyoke range in Massachusetts. Moreover, this correlation of faint folds with faults explains the order of overlays or offsets in the successive ridges of a curved range; at the southern end of a crescent, the upthrow on the eastern side of the faults produces the advancing order, seen in miniature at the southern end of Pond Mountain, and in a much larger way along the Hanging Hills and as far north as Talcott Mountain; at the northern end of a crescent, the same upthrow produces the opposite overlap, or receding order, as in the little ridges of the range that crosses the Mattabesick at Beckly station, or again in the peaks of the Holyoke range.

The topography of Pond and Toket Mountains (Percival's E, I and E, II) is particularly instructive when thus interpreted. Pond Mountain is the simpler of the two, and is especially interesting from the appearance of its posterior ridge in an almost complete oval, the only example in the whole valley where the outcrop of a trap-sheet on the eastern side of its flat, dish-like fold is not cut off by a fault. The escape here is by only a few hundred feet, for the crystalline rocks appear close by. Such an eastern outcrop explains the steep slope and convexity of the ridge to the eastward, instead of to the westward, as is elsewhere the universal rule; and it is with no small satisfaction that so pronounced an exception to the rule is found to be so completely in accord with the explanation proposed for the structure of the formation: the exceptional case might have been predicted before observation. Toket Mountain is not separated from Pond Mountain by a fault, but by erosion on a transverse flat arched anticlinal, clearly defined by the dip of the adjacent conformable sandstones. Toket itself is divided into two unequal lobes by a faint indentation north of its middle; and from an examination of the dip of the accompanying sandstones it becomes clear that this indentation results from a faintly developed transverse anticlinal, of the same kind as that which, when carried farther, has caused the separation of the Pond and Toket crescents in the present stage of erosion. Indeed, the fate of separation has already overtaken the ridge posterior to Toket, which is cut into two crescents just opposite the indentation between the two lobes of the main mountain.

1.

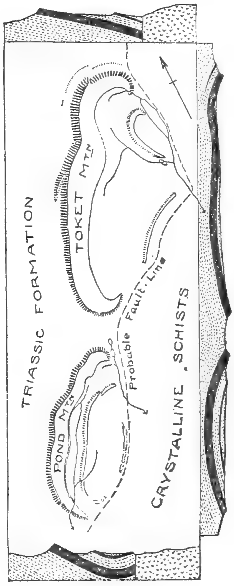

Fig. 1.—Pond and Toket Mountains, enlarged from Percival's outline. A transverse section is given for each mountain and a longitudinal section runs through both.

There is good reason to think that the wide separation of the Mount Holyoke and Deerfield trap ranges in Massachusetts is due to a similar transverse uplift, but of much greater value: for on this supposition we should expect to find the lowest members of the formation exposed about midway between the strong eastward curves of the ranges; and surely enough it is in precisely this position that the fundamental crystalline rocks of Mount Warner appear, and they have no other outcrop within the limits of the Triassic formation. The combination of faults and faint, dish-like folds in the way here outlined is therefore not only allowed but demanded by the topography; and there is good promise that the intricate maze of ridges represented on Percival's map may be reduced to system when their many forms are interpreted as slight variations on one or two simple types of structure. The trap ridges of the little Woodbury-Southbury Triassic area in Western Connecticut present the same types of structure and much was learned from their examination. The explanation of the Triassic disturbance by external forces must for these reasons devise a mechanism for the production of a faulted monoclinal, in which the faults will have their upthrow of varying value on the side toward which the beds dip, and in which a more or less pronounced "dishing" of the beds may appear on a larger or smaller scale.

A few years ago, it was suggested* that certain disconnected Triassic areas with opposite monoclinal dips might be regarded as the buttress-like remnants of great anticlinal arches, the larger part of which had been consumed by erosion. From what has already been said, it is apparent that a simple, unfaulted anticlinal cannot be accepted, at least for the Connecticut buttress of the Connecticut-New Jersey arch; and the former continuity of the Triassic beds over the crown of the arch, so as to cover all the surface between the present limits of formation, is not only unproved by independent evidence, but is unnecessary to the hypothesis; for it is clear that if the foundation, on which the Triassic strata rested, were greatly elevated in the Western Connecticut region, the strata would be tilted in opposite directions on the two sides of the elevation, whether they ever stretched across it or not. But whatever was the former area of the Triassic deposits, the suggestion that their disturbance was physically connected, and that it involved the disturbance of a much larger area of the earth's crust than that which they now cover, is a point of fundamental importance. It has been too much neglected because the rocks about the Triassic areas are so generally crystalline schists and gneisses, whose disturbance is not easily recognized. The absence of tilted sedimentary rocks all over Southwestern New England cannot be taken as evidence that no post-Triassic tilting occurred there; on the other hand, the little Woodbury-Southbury Triassic area gives direct evidence—not of the former continuity of the Triassic strata from Connecticut to New Jersey—but of the continuity of the disturbing action all across this district. So wide a disturbance must have had a deep penetration; and the faults in the Triassic areas give sufficient evidence that the dislocations were not limited to the relatively superficial coating of Triassic strata. Some of the faults have a throw of several thousand feet—for example, the

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* Independently by Kerr (1874) for North Carolina, and by Bradley (1876) and Russell for Connecticut and New Jersey.

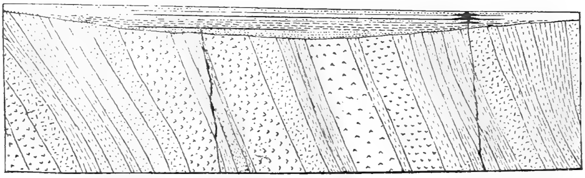
one that separates Lamentation Mountain from the Hanging Hills—and if drawn on true scale it cannot be supposed that displacements of so great a measure could fade away within the thickness of the Triassic beds, even if they were ten or fifteen thousand feet thick. The faults must penetrate to a depth many times greater than their throw; to a depth commensurate with their length, and this may be five or ten miles. This gives us literally a deeper insight into the Triassic disturbance, and points out another important requisite in the hypothesis for its explanation: the disturbance must affect not only the Triassic rocks, but a broad and deep mass of the earth's crust with them. Attention has been too generally given to the Triassic rocks alone; it will be well to invert the problem, and look for a time at the underlying schists and gneisses to discover how they may have yielded to a disturbance; letting the superficial covering of Triassic beds take the consequences of it, and adapt themselves to the dislocation of the surface on which they rest as best they may.

The fundamental rocks are great slabs of crystalline schists and gneisses, varying strongly in composition and texture. Some are massive and almost granitic; others are finely foliated. The attitude of the slabs is hardly more constant than their composition; but they are in general more nearly vertical than horizontal, and their prevailing strike is north or east of north. The Triassic strata were laid down on the edges of these steeply inclined slabs after they had been bevelled off to a tolerably even surface by pre-Triassic erosion. The character of the deformation of the schists would depend on the action of the deforming forces.

The general position of the Triassic areas as well as the detail of their structure at once suggests their connection with the Appalachian system of disturbances. The depression of the long trough-like areas in which the Triassic strata accumulated as well as the subsequent disturbance of the accumulations is most naturally referred to a late manifestation of the forces that had at an earlier date produced the great system of Appalachian folds; and as such should be regarded as the results of a slow, irresistible, horizontal crushing force or compression, acting east and west or southeast and northwest. No definite limit can be set to the depth through which the compression acted; but judging by its effects in the writhing and folding of the Appalachian strata, it must have had a profound penetration; and if the theories that have been suggested to account for the compression may be trusted at all as guides, the thickness of earth's crust affected by it must be measured by tens or even hundreds of miles.

A group of inclined slabs, compressed by a horizontal force about at right angles to their strike, might yield in part by minute internal rearrangement, and in part by slipping on their divisional surfaces, so as to reduce their breadth by standing more nearly vertical, that is, more nearly at right angles to the compressing force. In so doing, the upper surface of the group would be somewhat elevated, and at the same time the bevelled edge of every slab would be tilted over by a tolerably constant angle in one direction, and separated from the neighboring slabs by a dislocation with the uplift on the side of the direction of dip. In case the compression varied at different depths, diminishing downwards, a shearing force would be introduced, by which the slabs could be thrown over past the vertical. It seems as if some such mechanism as this might account for the faulted monoclinal structure of the overlying Triassic strata, which must follow its hidden action.

2.



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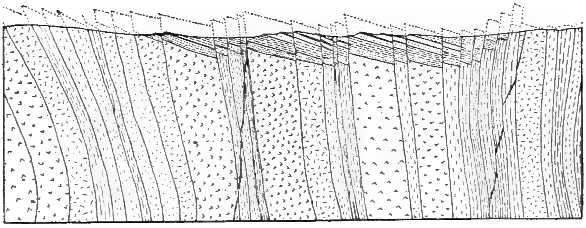

Figs. 2 and 3.—Hypothetical sections to illustrate the relation of the Triassic strata to the schists which they overlie unconformably. The dikes that supply the intrusive and overflow sheets of trap are drawn in assumed positions; the simplicity of the attitude of the schists is without doubt much exaggerated. When the breadth of the section in the first figure is reduced by a compression that reaches to a much greater depth than the sections include, the slabs of schist slip on one another so as to take more nearly vertical positions; and the overlying beds are thereby broken into blocks and canted over into a monoclinal attitude, with a dip equal to the change in the inclination of the schists; the faults between the blocks have their upthrow constantly on the east. It is not desired to affirm that the fault planes are in continuation of the foliation of the schists. The hade of the faults has not been determined.

It is difficult to consider all the natural possibilities of such a process. The number and closeness of the faults would depend on the texture of the schists: the more numerous and closer the faults, the less would their throw generally be. A change in the number and throw of the faults along their strike would warp the upper surface into flat, dish-like corrugations.

According to this hypothesis, the fissures which divide the Triassic strata into long, relatively narrow blocks are to be regarded as determined by the divisional surfaces between the slabs of the underlying schists; as such, the direction of the Triassic faults should correspond with the strike of the underlying schists. This must be the explanation of the oblique, north-northeast direction of the topographic outlines from Hartford to the Sound: for Percival's map shows a broad belt of schists, with strike about north-northeast, approaching and running under the Triassic area at its southwestern margin near New Haven, directly towards the Hanging Hills, where the obliquity of the fractures between the trap ridges is so well seen; continuing nearly in the same direction, the eastern margin of the Triassic area is found bordered by schists with similar strike, from Glastonbury to Stafford.* The strike of the buried schists determines the strike of the surface structure and topography; and as the correspondence of these two apparently independent elements was first noticed after the reason for it came to mind, it seemed to me a valuable confirmation of the hypothesis here presented. Nearly all the ridges of this southern district overlap in advancing order, because the faults, with upthrow on the east, here trend a little to the right of the strike of the trap-sheets, with dip to the east. Where the overlap is receding, it is because the ridges have curved so far to the east that the faults run to the left of their strike, as in Berlin and southern Wethersfield, or on the northern hooks of the Pond and Toket crescents. There is also a necessary correlation between the throw of a fault and the amount of overlap and offset that it will produce: the fault between the Hanging Hills and Lamentation Mountain has probably the greatest throw of any yet found, and the greatest overlap and offset is found between the same ridges. The unique topographic details of the district thus find a simple explanation in the structure that results directly from a single process of mechanical disturbance.

The receding order of overlap in the range of the Barndoor Hills of Granby and Simsbury offered opportunity of making further test of the correspondence between the strike of the schists and the trend of the faults and the resulting displacement of the ridges. Between Simsbury and Canton, the range bears north and south; the underlying and neighboring schists should therefore run west of north, so that their strike shall be

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* Percival noticed this alignment, but doubted the continuity of the schists across the Triassic depression. Geol. Conn., 222, 289, 290.

to the left of that of the ridges. Farther north in Granby, the range turns to the northeast, and here a north and south strike of the schists would produce a receding overlap. Having determined this from the conditions of the hypothesis, the mazes of Percival's text were searched through with care, and it was then found that the schists in Canton, close to the first-named ridges, dip to the east-northeast, and therefore strike to the north-northwest (Geol. Conn., p. 78); while in the second locality, the schists strike about north and south (Id., pp. 75, 293, 294). Further tests of this nature will be made by additional observation in the field.

There is a difficulty in the operation of the mechanical disturbance that should be referred to. The faults are sometimes so close together, that it is not easy to imagine them extending downward across the whole series of underlying beds without causing irregularities of dip; and yet no such irregularity is thus far discovered. But it may perhaps be that the present surface of the ground was so deeply buried during the initial stages of the disturbance, that the weight of the superincumbent mass, or gravitative form-destroying force, was then and there greatly in excess of the strength of the rocks, or cohesive, form-preserving force; in such case, the fractures would follow closely along the planes of greatest stress as indicated by the slabs of schists, and once formed they would long remain the surfaces of easiest displacement. However this may be, the hypothesis seems to accord well in its essential features with all observations yet collected, and to possess something of the prophetic power that may in time entitle it to be called a theory. It may perhaps find application in other regions where unconformable masses have been deformed together, and the lesser, superficial mass has to accommodate itself to the forms presented to it by the greater mass beneath. When compression overtakes the region of northern France, where the massive and steeply inclined coal-measures are covered unconformably by a relatively thin sheet of Cretaceous strata, the latter may be broken up into a number of tilted blocks, not unlike our Triassic. It may be that even so great a faulted monoclinal as that of eastern Tennessee owes a good part of its structure to the reaction from its crystalline foundation.

ART. XL.—*Researches on the Lithia Micas;*[*] by F. W. CLARKE.

I. THE LEPIDOLITES OF MAINE.

IN the western part of Maine, along a line running southeasterly from the Rangeley Lakes to a point on the seaboard between Brunswick and Portland, there are a series of veins of albitic granite which are noted for their contents in lithia mica and colored tourmalines. These localities, in the towns of Rumford, Paris, Norway, Hebron and Auburn, are all within a narrow belt of about forty miles in length; and with them, as a probable part of the same system, may be classed the spodumene locality in the town of Peru. The northernmost of the known localities is that on Black Mountain in Rumford; but a few fragments of inferior green tourmaline have been found about five miles farther north, in Roxbury—a fact which indicates a prolongation of the belt in that direction. Similarly, a southern extension of the belt is suggested in the territory covered by the towns of Pownal, Yarmouth and Freeport, a region from which a few casual specimens of lepidolite have been reported. The total width of the belt, so far as has been observed, appears to be not much over fifteen miles, although sharp definition of the area is not yet possible.

In general character the several localities are much alike, although in points of minor detail they vary considerably. With the tourmaline and lepidolite, quartz, muscovite, cleavelandite, cassiterite and amblygonite are always found, together with a wide range of other species which cannot be considered here. Some of the differences are probably due to the fact that certain localities have been more thoroughly opened up than others, and these differences would probably be eliminated by more complete exploration. In other points, however, the variations are notable and characteristic. For convenience we may briefly consider the several localities separately, beginning with the northernmost and proceeding southward in regular order.

Rumford.[†]—This locality, discovered in 1878 by Mr. E. M. Bailey, of Andover, Maine, is situated on the northern slope of Black Mountain, at an estimated elevation of about one thousand feet above the valley. The excavation, so far, has been merely superficial. A part of the lepidolite, which is very abundant, is fairly pure, lilac-purple in color and finely granular; but the larger portion of the mineral is coarser in structure and thickly sprinkled with small, opaque, red tourmalines.

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[*] Abstract of a paper to appear in full in a forthcoming Bulletin of the U. S. Geological Survey.

[†] See G. F. Kunz, Proc. Amer. Assoc., 1885.

The color of the latter is very rich and the appearance of the material carrying the associated minerals is strikingly characteristic. It resembles nothing from the other localities of the region. Green tourmaline occurs here but sparingly, while the spodumene is enormously developed, showing faces over a metre in length. At the other lepidolite localities spodumene is one of the scarcer minerals.

Paris.—The famous locality known as Mt. Mica has been so thoroughly studied by mineralogists that no detailed account of it is needed here. The lepidolite occurs both in the ordinary, purple, granular form and in broad foliations resembling muscovite. Analyses of it have been published by Berwerth and by Rammelsberg,* which agree fairly well with the results obtained in this laboratory.

Hebron.—The deposit at this point, about seven miles southeast of Mt. Mica, has long been well known to collectors. It has only been superficially opened, however, and deserves more systematic exploration. The lepidolite, which is coarsely granular and purple, is especially interesting on account of its yield in cæsia and rubidia, which, after their identification by Johnson and Allen here, were also found in the lepidolite of Rozena. As yet no complete analysis of the Hebron mineral seems to have been published. For the specimens examined in this laboratory I am indebted to the kindness of Professor G. J. Brush.

Associated with the Hebron lepidolite there have been found many specimens of red and green tourmaline, which, while preserving their crystalline form, have undergone an alteration into a softer mineral of an opaque, talcose appearance. Some of the material so derived from tourmaline has been supposed to be lepidolite; and as it was possible that a study of it might have interest, an analysis was made by Mr. R. B. Riggs. The specimen chosen was originally rubellite, and its specific gravity, as determined by Mr. T. M. Chatard, was 2·87. Analysis as follows:

SiO_2	43·90
Al_2O_3	38·71
Fe_2O_3	·58
FeO	·25
MnO	·04
CaO	.41
MgO	·05
Na_2O	1·05
K_2O	10·92
H_2O	4·25
F	none
B_2O_3	trace
	100·16

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* See third supplement to Dana's Mineralogy, pp. 78, 79.

These results show clearly that the alteration product is not lepidolite but damourite, a fact which could hardly be altogether unexpected. The material analyzed was received from Mr. N. H. Perry of South Paris, Maine.

Norway.—The specimens from this locality were partly collected during a field expedition, and partly received from N. H. Perry. The lepidolite was of two varieties; one, pale brown and very finely granular, the other much coarser in structure and white. Most of the associated tourmaline has a peculiar, dark oily-green tint; and with many of the specimens a rose red earthy clay was associated. A partial analysis of the latter was published in Bulletin No. 9 of the U. S. Geological Survey, but a re-analysis seemed to be desirable and was therefore made by Mr. Riggs. The results are subjoined and show that the mineral approaches nearly to cimolite. The difference from the earlier analysis indicates a non-homogeneity of composition. As to the genesis of the clay, nothing can be said with certainty.

SiO_2	66·86
Al_2O_3	22·23
Fe_2O_3	·47
FeO	·18
MnO	·07
CaO	·42
MgO	·33
Li_2O	·29
Na_2O	·46
K_2O	·18
H_2O	8·26
F	·06
	99·81

Formula, $Al_2H_4Si_5O_{15}$.

Auburn.—In the western part of this town, near the Minot line, there are two localities for lepidolite, less than half a mile apart. The one longest known is small and unimportant, but the other on the farm of G. C. Hatch, has been quite thoroughly developed.* It has yielded many gem tourmalines, mostly of the paler tints, some remarkable apatites, and perhaps the best crystallizations of lepidolite so far known. The latter mineral occurs in the ordinary purplish, coarsely granular form and also in extraordinary perfection as a border upon muscovite; the broad plates of the latter being practically encircled by aggregations of small crystals of the lithia mica. Some specimens of this type have also been found at Paris.

As it was hoped that this mode of occurrence of lepidolite might throw some light upon its genesis, three analyses of Auburn material were made by Mr. Riggs: first, of the com-

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* See G. F. Kunz, this Journal, III, xxvii, 303.

mon granular variety, secondly of the border upon muscovite, and finally of the latter mineral from the center of the second specimen. The muscovite analysis came out as follows:

SiO_2	44·48	Na_2O	2·41
Al_2O_3	35·70	K_2O	9·77
Fe_2O_3	1·09	H_2O	5·50
FeO	1·07	F	·72
MnO	trace		
CaO	·10		100·84
MgO	trace	Less oxygen	·30
Li_2O	trace		100·54

About these results there is nothing unusual.

For convenience the analyses of lepidolite, all by Mr. Riggs, may be given in one table. The water in every case was determined directly by means of the Gooch tubulated crucible, and most of the lithia separations were effected by a new process, lately devised in this laboratory by Dr. F. A. Gooch, and shortly to be published in full. In the Auburn and Norway lepidolites, however, the old phosphate method was used. The fluorine estimations were all by the Berzelian process. In the figures given for $(KRbCs)_2O$, we have actual determinations based upon the amount of chlorine in the mixed chlorides, and not a mere computation as K_2O from the weight of the chloroplatinates. All important estimations were checked in duplicate, and the table of results represents mean values. Seven analyses were made, as follows:

Analyses of Lepidolite.

	A. Purple. Rumford.	B. Foliated. Paris.	C. Granular. Hebron.	D. Border. Auburn.	E. Granular. Auburn.	F. White. Norway.	G. Brown. Norway.
SiO_2	51·52	50·92	48·80	49·62	51·11	49·52	50·17
Al_2O_3	25·96	24·99	28·30	27·30	25·26	28·80	25·40
Fe_2O_3	·31	·30	·29	·31	·20	·40	.87
FeO	undet	·23	·09	·07	·07	·24	·45
MnO	·20	trace	·08	·55	·17	·07	·23
CaO	·16	trace	·10	----	·12	·13	undet
MgO	·02	trace	·07	----	·01	·02	undet
Li_2O	4·90	4·20	4·49	4·34	4·98	3·87	4·03
Na_2O	1·06	2·11	·74	2·17	1·43	·13	13.40
$(KRbCs)_2O$	11·01	11·38	12·21	11·19	12·25	12·63	
H_2O	·95	1·96	1·73	1·52	·94	1·72	2·02
F	5·80	6·29	4·96	5·45	6·57	5·18	5·05
	101·89	102·38	101·86	102·52	103·11	102·71	101·62
Less oxygen	2·44	2·64	2·02	2·29	2·76	2·18	2·13
	99·45	99·74	99·84	100·23	100·35	100·53	99·49

As regards cæsium and rubidium the Maine lepidolites offer some points of difference. In the Rumford material an ordinary analysis shows neither; but a special examination upon the alkalies from 150 grams of mineral gave a spectroscopic trace of rubidium. The Paris lepidolite showed traces of both metals, while the material from Hebron, Norway and Auburn was much richer. On these lepidolites approximate estimations were made, as follows:

	Hebron. Granular.	Norway. White.	Auburn. Granular.	Auburn. Border.
K_2O	11·44	8·82	10·51	8·03
Rb_2O	·77	3·73	1·29	2·44
Cs_2O		·08	·45	·72
	12·21	12·63	12·25	11·19

In these determinations the cæsium was separated as stannic chloride, and the other two metals were computed indirectly from the amount of chlorine in the mixed chlorides. The results have only a comparative value, and no sharp accuracy can be imputed to them. The methods of separation for the three metals are still far too defective.

The foregoing analyses of the Maine lepidolites, covering several distinct types of the mineral from five different localities, indicate a great constancy of composition. The essential identity of the mineral with that from Rozena and Cornwall is also shown by the several published analyses of the latter, while the lepidolite from Juschakova is slightly different, in that it contains some manganese replacing aluminum, higher fluorine and a little chlorine. In most of the analyses the water and fluorine appear to vary reciprocally, suggesting the ordinary replacement of the latter element by hydroxyl. With this slight assumption the formula for lepidolite may be written thus:

$$Al_2LiKF_2Si_3O_9\,;$$

a formula which has long had general acceptance, but which now rests upon the surer basis of a wider range of analytical data. It corresponds to the following theoretical composition:

	Calculated.		Found.		(Riggs).
SiO_2	49·18		48·80	to	51·52
Al_2O_3	27·87		24·99		28·80
Li_2O	4·09		3·87		4·98
K_2O	12·81	$(NaKRbCs)_2O$	12·07		13·68
F	9·84	(FH_2O)	6·69		8·25

Most of the variations are no greater than we should expect to find in material so difficult to secure in absolute purity as lepidolite. The granular structure of that species is peculiarly favorable to the presence of inclusions, as for example of albite, to which probable impurity some of the soda shown by the analyses may be due. The greatest difference is in the case of fluorine; although some of the foreign analyses, notably Rammelsberg's analysis of the Juschakova mineral, contain very nearly the full theoretical amount.

II. THE IRON-LITHIA MICAS OF CAPE ANN.

In the granite quarries of Rockport, Massachusetts, near the extremity of Cape Ann, there are occasional feldspathic veins which contain the rarer minerals danalite, cyrtolite, fergusonite, and amazon-stone, together with certain remarkable micas. One of the latter, cryophyllite, was described by Cooke in 1867;* who also analyzed an associated "lepidomelane," to which Dana afterward gave the name of annite. The vein from which Cooke obtained his material was long ago blasted away or covered up; but other veins of like nature are still accessible, and from one of them the micas examined in this laboratory were obtained. They were collected by the original discoverer of the locality, Mr. W. J. Knowlton of Boston, and were, to all appearance, identical with the micas described by Cooke. Among the specimens the two types were clearly recognizable; the one a dark-greenish-black lithia mica, cryophyllite; and the other a black, brilliant lepidomelane. In some specimens the cryophyllite formed a border upon the broad plates of the other mica, precisely as in the association of lepidolite and muscovite at Auburn. The resemblance in this particular was curiously striking; only the Rockport minerals are less conspicuous than those from Maine, since they lack the contrast of color which gives the latter their beauty.

The cryophyllite varies considerably in outward character, and three well marked types of it were analyzed by Mr. Riggs. They may be described as follows: A. Broadly-foliated, brilliant, blackish-green. B. Paler, dull-green, less lustrous, seemingly altered. C. An aggregation of minute six-sided prisms, dark green, almost granular in appearance, resembling some chlorite. Mean results are given.

	A.	B	C.		Cooke's Analysis.
SiO_2	51·96	51·46	52·17		51·49
Al_2O_3	16·89	16·22	16·39		16·77
Fe_2O_3	2·63	2·21	4·11		1·97
FeO	6·32	7·63	5·99		7·98
MnO	·24	·06	·32	Mn_2O_3	·34
CaO	·12	trace	trace		----
MgO	·03	·17	trace		·76
Li_2O	4·87	4·81	4·99		4·06
Na_2O	·87	·89	·63		trace
K_2O	10·70	10·65	10·48		13·15
H_2O	1·31	1·12	1·46		----
F	6·78	7·44	7.02	SiF_4	3·42
	102·72	102·66	103·56		99·94
Less oxygen,	2·86	3·11	2·95		
	99·86	99·55	100·61		

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* This Journal, II, xliii, 217.

It will at once be seen that the three samples examined by Mr. Riggs were sensibly identical, and not far in composition from the material analyzed by Cooke. In the latter the fluorine amounted to 2·49 per cent, which is only about one-third of the figure found in this laboratory, while the silica, plus that represented in the SiF_4, is sensibly higher. The integrity of the species, however, seems to be clear; and it cannot be identified with zinnwaldite. Empirically, as deduced from the new analyses, the formula of cryophyllite may be written

$$FeH_3K_3Li_4Al_4F_4(SiO_3)_{10}; \quad \text{or,} \quad R'_6Al_2F_2(SiO_3)_5.$$

With the "lepidomelane" or annite, quite unexpected results were obtained. The material analyzed by Mr. Riggs was black, brilliant, broadly foliated, and apparently very pure. His figures are given in contrast with those published by Cooke.

	Riggs.		Cooke.
SiO_2	31·96		39·55
TiO_2	3·42		----
Al_2O_3	11·93		16·73
Fe_2O_3	8·06		12·07
FeO	30·35		17·48
MnO	·21	Mn_2O_3	·60
CaO	·23		----
MgO	·05		·62
Li_2O	trace		·59
Na_2O	1·54		trace
K_2O	8·46		10·66
H_2O	4·25		1·50
F	trace	SiF_4	·62
	100·46		100·42

It is at once evident that two entirely distinct micas are here represented, and the question is raised whether the Rockport granites may not contain a series of complex isomorphous mixtures. Cooke, indeed, pointed out the isomorphism of cryophyllite with his samples of annite, and showed that the lithia and fluorine in the latter were probably due to admixtures of the former. We now see that at least three micas are involved in the problem to be solved, and the difficulty of establishing definite formulæ is enormously increased. For the present, approximate formulæ only can be assigned to these micas, involving several assumptions, and representing probabilities rather than complete interpretations of the facts. If we unite the groups SiO_2 and TiO_2 in the new annite, and regard the ferric iron as belonging partly with the alumina, and partly as having been derived by oxidation from the ferrous state, we have the following general formulæ for the two analyses.

Annite, Cooke, $R'_8Al_4(SiO_4)_6$.
Annite, Riggs, $R'_{14}Al_2(SiO_4)_6$.

For the former, the equivalent of R'_8 is approximately $K_2H_2Fe''_2$, and for the latter it is $K_2H_4Fe_4$. These values correspond to the following percentage compositions.

	Cooke.	Riggs.
SiO_2	39·5	36.6
Al_2O_3	26·8	12·4
FeO	18·9	35·1
K_2O	12·4	11·5
H_2O	2·4	4·4
	100·00	100·00

Attention has already been called to the fact that some specimens of cryophyllite form borders upon plates of annite, precisely as the lepidolite of Auburn is arranged about nuclei of muscovite. It accordingly becomes quite probable that similar relations connect the two pairs of minerals; and upon these relations the formulæ so far deduced shed some light. In each case we have a mineral with metasilicate ratios implanted upon an orthosilicate; and a derivability of the one from the other is forcibly suggested. Structural analogies also appear; for in each couplet we have evidence of a common type of nucleus, which may be represented thus:

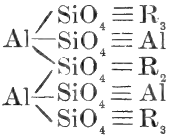
Lepidolite nucleus, $Al(SiO_3)_3$. Cryophyllite nucleus, $Al_2(SiO_3)_5$.
Muscovite nucleus, $Al(SiO_4)_3$. Annite nucleus, $Al_2(SiO_4)_5$.

The development of complete structural formulæ from these nuclei is rendered difficult by our ignorance of the part which fluorine plays in such compounds. In the ordinary lepidolites it is easy to conceive of it as united with the aluminum in the univalent group AlF_2; but in the iron micas and phlogopite a similar representation is unsatisfactory. A different solution of the problem is therefore to be sought, and it may be found by an application of the well-recognized principle that fluorine and hydroxyl can replace each other isomorphously.

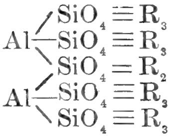
If now we start from orthosilicic acid, $Si(OH)_4$, and regard the hydroxyl groups as successively replaceable by atoms of fluorine, we can conceive of a series of acids ranging from $Si(OH)_4$ to SiF_4; and with the aid of such a supposition many of the fluoriferous silicates may be rationally explained. For example, the acid $SiF(OH)_3$ may be considered, and its nucleus, $SiFO_3$, a trivalent residue, can be applied to the discussion of the lithia micas. Upon this basis the formulæ for lepidolite and cryophyllite become curiously significant, especially when written in direct comparison with the structures assignable to muscovite and annite respectively. In every case the assumption is made that double salts are to be represented as substitution derivatives of normal salts of similar type, and the results appear as follows:

Muscovite.

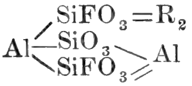
Annite (Cooke).



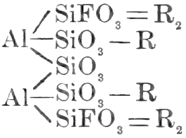
Annite (Riggs).



Lepidolite.

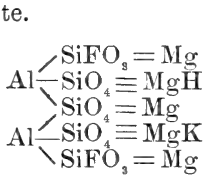


Cryophyllite.



To zinnwaldite, as represented by the published analyses, a probable structure is not easily assignable; and the variations in its composition suggest that the specimens examined have been mixtures of isomorphous compounds. It needs to be thoroughly reinvestigated, not only for itself, but also in its relations to whatever other micas may be associated with it. The matter of association can never, in the study of the micas, be safely neglected.

Although the formulæ herein assigned to annite and cryophyllite are to be regarded merely as trial hypotheses, there can be little doubt that the ratios between the sesquioxides and the silica are correctly given. These ratios are the ratios indicated by the published analyses of phlogopite; with which, therefore, rather than with ordinary lepidomelane, the Rockport micas are chemically to be classed. Zinnwaldite is already so classed by Tschermak and others, and cryophyllite falls easily into the same category. The subjoined formula fairly represents a typical phlogopite.



ART. XLI.—*The thickness of the Ice in Northeastern Pennsylvania during the Glacial Epoch;* by JOHN C. BRANNER.

THE thickness of the ice in northeastern Pennsylvania during the Glacial epoch was supposed, from such evidences as those who have studied the region were able to find, to have been indicated by the absence of striæ, bowlders or ice-worn fragments above an elevation of 2,200 feet above tide, upon the sides of the highest hills in that part of the State. These high points are Sugar Loaf peak, Ararat peak and Elk Mountain. The first two are the straggling continuation of the Lackawanna coal basin beyond where the Moosic range and the Lackawanna mountains coalesce. They are in Wayne County, almost upon its boundary with Susquehanna County, and about sixteen miles north and a little east of Carbondale. The summit of Sugar Loaf is 2,450 feet, and of Ararat peak 2,600 feet above tide, according to Professor I. C. White, who has reported upon this region.* Elk Mountain is in Susquehanna County, about ten miles north and a little west of Carbondale. It culminates in a pair of peaks known as North and South Knobs, which are respectively 2,700 and 2,575 feet above tide according to Professor White's measurements.

These several peaks are the highest points in the northeastern part of the State, and stand up boldly above the surrounding country, the valleys being eroded away about them to a depth of from 500 to 1,500 feet.

Professor I. C. White refers in several places to the absence of evidence that these peaks were covered by the ice, and they are spoken of, both by himself and by Professor H. C. Lewis, as having stood out like islands above the ice of the glacial epoch. Speaking of Ararat and Sugar Loaf, Professor White says:† "These summits, which probably existed as elevated hills in preglacial times, were left as islands in the ice moving southward, and escaped the universal abrasion to which every other portion of the township was subjected; for no appearance of drift or glacial scratches can be found on their sides or summits." In another place (ibid., p. 25) he speaks of "such isolated peaks as Elk Mountain, Ararat, and Sugar Loaf—the summits of which were islands in the *Mer de Glace*, and thus escaped its action." On the same page he says: "2,200 feet above tide is the greatest elevation at which I have observed direct evidence of glaciation, either in the shape of morainic *débris* or striated rock surfaces. All higher summits which I

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* Report G5 of the Second Geological Survey of Pennsylvania.

† Report G5, Second Geol. Survey of Pa., pp. 158, 159.

have examined are destitute of drift deposits." Professor H. C. Lewis also refers* to these peaks as having stood up as islands in the sea of ice. He refers† to the evidence of ice action on the summit of Penobscot Knob, in Luzern County, at an elevation of 2,220 feet above tide, only twenty feet higher than the limit mentioned by Professor White. These, then, are the highest points in the State of Pennsylvania at which unquestionable evidences of ice action have been observed and recorded, namely : at 2,200 feet by Professor White upon the sides of the high peaks, and at 2,220 by Professor Lewis upon Penobscot Knob.

Having given attention to the glaciation of the region under consideration,‡ I was deeply interested, upon visiting this part of the State in July of the present year, to see and examine for myself the evidences of the thickness of the ice upon the sides of Elk Mountain, said to be the highest point in northern Pennsylvania.

Ascending this mountain by the path leading to the south knob, I found upon the ledge of rocks forming the principal outlook over the surrounding country, well defined glacial striæ. Those upon the east side of the ledge bear S. 60°–65° W., while those upon the west side bear S. 70°–72° W., magnetic. Professor White makes the elevation of this point 2,400 feet above tide. This observation alone therefore indicates that the ice was thicker than Professor White supposed.

Ascending to the summit of the south knob, I found nothing along the brushy sides of the peak to indicate ice action. On the summit itself, now covered with woods, the decay of the rocks has left nothing, as far as I could see by hastily made observations, to show whether or not the peak was ever covered by the ice. In the hope of finding a more resisting rock, and consequently something more conclusive, upon the higher north knob, in company with Professor Dudley, of Cornell University, Mr. D. N. Green, of Scranton, and with several of the younger members of my class in geology, I visited that part of the mountain which lies a mile farther to the north.

As the whole of the upper part of these peaks is covered with a thick undergrowth of bushes and briars, it is not possible, while the plants are in full foliage at least, to get any idea of the arrangement of loose material about the sides or summit, or of the best places to see the rocks in position. My observations, therefore, were confined to such fragments and outcrops as we happened upon in passing from one peak to the other.

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* Report Z of the Second Geol. Survey of Penn., pp. 14, 15.

† Report Z, p. 106.

‡ "Glaciation of the Wyoming and Lackawanna Valleys," in Proc. American Philosophical Society, 1886, No. 123, pp. 337–357; and Glaciation of the Lackawanna Valley, in Proc. A. A. A. S., vol. xxxiv, p. 212.

In the depression between the two, at an elevation of about 2,400 feet, I found the rocks presenting the general features of ice-worn surfaces; but inasmuch as there were no striæ preserved, and as the original surface of the not very hard Catskill sandstone had generally disintegrated, it could not be said with certainty that the form of the rock had been produced by glaciation. Many large fragments, and some of the sandstone seen in place before reaching the summit of the north knob, seemed to indicate ice wearing. But in no case were these evidences beyond some question, owing always to the original surfaces having been degraded by weathering. From several of the ledges we turned back the thin soil, but the laminations of the decaying rock always came away with the turf.

Upon reaching the top I was at first greatly disappointed in finding no exposures of the rock in place. The summit area is a small flat space of less than half an acre of ground, most of which has been cleared of its brush by a triangulating party which has used this peak as one of its stations. Mr. Green and I, in the hope of finding some exposed rocks in place on the side where ice marks are most liable to be found, passed over the summit and a short distance down the north side, and then skirted around the peak toward the east. At an elevation of 2,530 feet I found what seemed to be evidences of ice action upon a rock immediately overlying the Catskill red, shaly sandstone. At 2,550 feet I found another fragment worn flat, evidently by ice, but retaining no well-defined striæ. Climbing up again toward the top of the peak along the eastern flank, I found that the crest of the knob was bordered on this side by a perpendicular ledge of rock, some ten or fifteen feet high, about the base of which were strewn many large, angular fragments. Climbing this ledge to the table-topped summit again, I was struck by the general flatness of this point and by the somewhat rounded appearance of the northern margin of this ledge. A narrow strip of the rock, from one to three feet wide, was exposed along the verge of the ledge. This bare space is being gradually encroached upon and covered by the moss and thin turf of the summit. The whole appearance of the rocks along the moss-covered edge was so suggestive of ice wearing that I examined all the exposed surfaces with the greatest care. My search was finally rewarded by finding positive and unquestionable evidence of glacial action. The original glaciated surface had been preserved on this exposed rock in one place over an area of three or four square inches, and this surface was ice-worn, polished and striated; all about it was more or less weathered. Turning back the mossy soil a couple of feet, we laid bare a number of striæ a foot or two in length and as well defined as any I have ever seen. They bear S. 34° W., magnetic. The point at which these striæ were observed is about fifty feet southeast of the triangulation station on the summit of the north knob of Elk Mountain. The elevation of this knob, according to Professor I. C. White, is 2,700 feet above tide.*

It has been supposed hitherto that we could measure the thickness of the ice in this part of the country upon the sides of these high peaks. The finding of well-defined striæ upon the very summit of the highest of them leaves us without a measure for the thickness of the ice in northeastern Pennsylvania. Other high points, such as Ararat, 2,600 feet, and Sugar Loaf, 2,450 feet above tide (White), only seven miles away and lower than Elk Mountain, must, almost necessarily, have been buried beneath the ice, although Professor White found no evidences of ice action upon their summits. The whole range of the Lackawanna Mountains northeast of the Susquehanna gap at Pittston has been examined by the writer. Evidences of glaciation were found upon its highest points along its entire length, or as far at least as Stillwater, above Forest City, where the Lackawanna River cuts through the range. The top of Bald Mountain, perhaps the highest point in this part of the range, and about 2,200 feet above tide, is striated in many places, while many bowlders, which seem to have been pushed up the northwest face of the mountain from the ledge not far below, are scattered over its summit. The striæ upon this eminence bear S., S. 6°, 10°, 11°, 20°, 25°, 33° W.

All my observations along the summit of the Lackawanna Mountains, and upon the high points here referred to, go to show that the great body of ice- and water-worn material ends long before the highest elevations are reached. In ascending Elk Mountain I did not see a single water-worn fragment above about 2,100 or 2,200 feet, though it would be extremely rash, of course, to say that such fragments do not exist above this elevation. This observation agrees entirely with those of Professor White.

It cannot be said that the disappearance of what was supposed to be the measure for the thickness of the ice in northeastern Pennsylvania, upon the sides of Elk Mountain, was altogether unexpected. The study of the topography and glaciation of the Lackawanna and Wyoming Valleys had already

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* Report G5, Second Geol. Survey of Pa., p. 136. I have used the elevations given by Professor White for these summits, because he checked and re-checked them from Herrick Center, four miles away. When not otherwise specified, the measurements mentioned in this paper have been furnished me by Mr. D. N. Green, of Scranton, who used the railway elevations at Carbondale or Scranton as a base. I believe his elevations have not been checked. He does not make the elevation of the north knob of Elk Mountain as great as Professor White by sixty feet.

led me to believe that it would have been impossible for a sheet of ice 1,500 feet or less in thickness to flow across this mountainous region so utterly regardless, as the great glacier was, of its marked topographical features.

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ART. XLII.—*On the time of contact between the Hammer and String in a Piano*;* by CHARLES K. WEAD.

HELMHOLTZ has, as is well known, developed a theory of the action of the hammer on a piano string. If the two remain in contact for a time equal to $\frac{3}{14}$ of the period of vibration of the string, the relative strength of the overtones as computed seems to be about the same as he found in a piano between the limits $C_{,}=33$ d. v. and $c'=264$ d. v. But in the theory there are several assumptions, and it cannot be confirmed by judgments of the ear alone; for we do not yet know certainly, even if Fechner's law be true, what is the proper measure of the stimulus of a sensation; is it the energy of vibration as Helmholtz assumes, or the square root of it as others have tried to prove, or some less simple function? Further, how is the loudness of a sound, that is, the strength of the sensation, dependent on the pitch of the sound, when several sounds have the same intensity in mechanical measure? Lastly, have we any proof that the relative strength of the component vibrations in the air-wave is the same as in the string? Although the quality of the sound may remain unchanged as the vibration of the string dies away, we have, I believe, absolutely no proof that the efficiency of the sounding-board, bridge, etc., is the same for all tones of the scale or for all the overtones of a given string.

It has therefore for a long time seemed to me desirable to measure directly the time of contact—an experiment far easier than the settlement of any one of the doubtful questions just referred to. The results of some preliminary measures are, I think, of sufficient interest and accuracy to justify their presentation.

The method used is quite simple. An electric circuit was completed through a cell, a resistance-box, a galvanometer, a fine wire around the stem of the hammer, a slip of gold-foil (about $\frac{1}{20000}$ inch thick) glued to the face of the hammer, and lastly, the piano wire and frame. The contact between the hammer and string produces a momentary closing of the circuit and a throw of the galvanometer needle, from the

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* Presented before the Am. Assoc. Adv. Science, at the Buffalo meeting.

amount of which the time of closing may be calculated. The minimum resistance of the circuit when closed by holding up the hammer was 2·7 to 3·0 ohms, to which a 10-ohm coil was added to diminish the uncertainty arising from any variable battery- or contact-resistance and to reduce the deflection. A telescope and scale were used at a distance of 1·6 meters.

The piano used was a Knabe Grand, put at my disposal by my former colleague, Professor C. B. Cady, who believes that such studies as these may throw light on the technically important subject of "touch." The *b* (just below middle *c*) was found on comparison with a Koeing's fork to make 255·4 d. v.; therefore $c'=270{\cdot}6$ d. v.

From the theory of the ballistic galvanometer we get the equation

$$t=\frac{T}{\pi}\times\frac{R\vartheta}{R'\vartheta'}.$$

t = time in seconds of momentary closing of circuit.
T = time in seconds of single vibration of galvanometer needle.
R = resistance of circuit.
R' = resistance of circuit when a constant deflection was observed.
ϑ = throw of needle, in scale divisions.
ϑ' = constant deflection, in scale divisions, with R' ohms in circuit.
$T = 5{\cdot}87$ sec. $R = 13$ ohms (12·7 for exps. 1 and 2).
$R'\vartheta' = 440000$.
$\therefore t = 0{\cdot}000055\,\vartheta$ seconds.

The correction for damping is so small that we may neglect it—about 2 per cent. The results of the observations are shown in the accompanying table.

No.	Tone.	No. vibr. n.	No. obs.	Mean. ϑ.	t. Sec.	$t\times n$.	Stroke.
1	$C_,$	34	11	92·0	·0051	0·17	
2			7	113·0	·0062	0·21	Soft.
3			3	94·0	·0052	0·18	
4			2	82·5	·0045	0·15	Hard.
5			1	102·0	·0056	0·19	Soft.
7			1	83·0	·0045	0·15	
8			1	108·0	·0060	0·20	Soft.
16			1	94·5	·0052	0·18	
6	C	67·7	3	52·5	·0029	0·20	
12	B	127·0	2	34·0	·0019	0·24	
12			2	38·0	·0021	0·27	Hard.
11	*c*	135·3	6	35·0	·00193	0·26	
10	c'	270·6	9	16·0	·00088	0·24	
	c''	-----	--	-----	-----	----	Broken.
13	c'''	108·2	3	28·0	·00154	1·68	
14			3	20·5	·00115	1·23	
15			2	18·5	·00102	1·11	

The observations for c''' are explained by the fact that the gold foil stuck to the wires and so increased the time of contact abnormally, but the time decreased as the foil was torn away. In all cases there was a slight click (much most easily noticed in the higher notes) showing that the addition of the foil, thin as it was, changed the quality somewhat.

The observations on $C_{,}$ were quite satisfactory and establish the unexpected fact that the contact-time for a very soft stroke is about 20 per cent greater than for an ordinary or hard blow (the very few contradictory observations on higher notes are not sufficient to disprove this conclusion); for an ordinary blow on this string the time is just $\frac{1}{6}$ of the period instead of ·21 as Helmholtz estimated.

NOTE ON COLLISION EXPERIMENTS.

While the apparatus used in the above experiments on the piano was set up, a measure was made of the time of collision between two ivory balls such as are used in the ordinary class-room experiments. Several experimenters have published their results for metallic balls, but I have seen none for ivory balls; and as such observations are fitted to do something toward clearing up, in the student's mind, the rather hazy subject of impulsive forces and their measurement, I add my results.

The constants for determining the time were the same as above except that R=15 ohms.

$\vartheta = 20$ div.

$\therefore t = \cdot 00129$ sec.

The diam. of the ball $= d = 3\cdot 9$ cm.

Its mass $= m = 55$ gms.

The radius of the arc over which the balls swung $= 67\cdot 5$ cm.

The chord of the arc $= 20\cdot 5$ cm.

$\therefore$ Final velocity $= v = 78\cdot 2$ cm. per sec.

$m\,v = 4301$ C. G. S. units.

Average force during contact $= mv \div t = 3276000$ dynes $= 3340$ gms.

Maximum force $= 6680$ gms. approximately.

Compression of ball $= s = \frac{1}{2}vt = \cdot 05$ cm. approximately.

Diameter of circle of contact $= 2\sqrt{ds} = \cdot 89$ cm. approximately.

Malone, N. Y., Sept., 1886.

ART. LXIII.—*Photographic Determinations of Stellar Positions;** by B. A. GOULD.

IT has been suggested that a short account of my work upon stellar photographs for the attainment of accurate observations might be acceptable to the astronomical section. My intention had been to attend this meeting as a listener and learner only; but I comply with the suggestion the more readily, since by a notable coincidence, I spoke upon the same subject in this place just twenty years ago, this week. It is true that my communication then was only an oral one and never reduced to writing; for the successful establishment of the Atlantic cable, of which I had received notice that day, called me away suddenly, before the time fixed for the regular presentation; but an elaborate written memoir upon the subject had been presented to the National Academy, ten days previous, at Northampton.

The early history of celestial photography is demonstrably and exclusively American; and its use as a method of delicate quantitative research is very markedly so. Without entering upon the historical data, which are of easy access to every investigator, I may mention that No. 77 of the *Astronomical Journal* contained nineteen photographic impressions of as many different phases of the solar eclipse of 1854, May 26—the moment of each impression being given to the nearest tenth of a second. These were taken at West Point under the direction of Professor Bartlett, of the U. S. Military Academy, and form a part of his memoir, in which he also gives the distances between the cusps, as measured by himself with the micrometer in the telescope. Ten years later, in 1864, Mr. Rutherfurd constructed the 11¼ inch photographic object glass which has acquired so conspicuous a place in astronomical history; and with this, in addition to its other achievements, he obtained sharp photographic stellar images with a definition previously unknown, taking for the first time distinct impressions of stars invisible to the naked eye—in fact, to the 8¾ magnitude for white stars.

After constructing a micrometer of great delicacy for the measurement of these plates, he measured with this the relative distances and position angles of the stars which they contained. And in the spring of 1866, he kindly placed in my hands the results thus derived from three plates of the Pleiades, each containing two impressions, taken on the evening of March 10.

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* Presented at the Buffalo meeting of the American Association for the Advancement of Science, August 20, 1886.

One of these plates contained forty stars. Bessel's memoir upon the Pleiades, published in 1844, gave the relative positions of 54 stars, measured with the Königsberg heliometer, during the years 1829 to 1841. Six of these 54 do not belong within the limits of the plate (which contains about one square degree), and 10 of them are too faint for the photographic record, so that 16 of Bessel's list are wanting; but, on the other hand, there are two additional ones, not observed by him.

From this fact alone it may be perceived that among the great benefits which astronomy may be justified in expecting from celestial photography, the accurate determination of magnitudes does not find place. The chemical action of the stellar light upon the film is so dependent upon the character of that light that, in the absence of a correct knowledge of its composition, we are very easily deceived regarding the amount. Thus one of Bessel's stars which was not recorded upon any of Mr. Rutherfurd's plates is estimated by Argelander as of the magnitude 8·0, and by Wolf as 7¾; while five are distinctly recorded which Argelander calls 8½ or less, and eight which Wolf so estimates. The spectroscope would doubtless show a deficiency of the more refrangible rays in the light of the former, and a preponderance of the same in that of the latter.

This series of measurements by Mr. Rutherfurd, together with the computations to which the results were submitted, constitute, if I am not mistaken, the first application of the photographic method to exact astronomical determinations. And the investigation necessarily demanded especial care, both for guarding the numerical results against sources of unsuspected error and for fixing the limits within which known theoretical errors would remain unappreciable.

The importance of the successful application of a method so different from all previous ones, and so full of promise, and also the considerable time which would inevitably elapse before the memoir could be printed, led me at the same time to communicate to the Astronomische Nachrichten, at Altona, some of the resultant values. In a comparatively short note, written about the middle of August, 1866, I gave for the ten most conspicuous stars of the Pleiades, after Alcyone, the corrections derived from one of the photographic plates of March 10, for the values, published by Bessel, of the position-angles and distances from Alcyone in 1840; as likewise the average discordance found for a single measure.

In the next following year the Academy had not the means of printing its memors; and, as, in the mean while, Mr. Rutherfurd had measured five more of the plates of the Pleiades previously taken, as well as six additional ones taken in the months of January and February, 1867, these were also computed, and the results added to those from the first three plates in the memoir already written.

Various circumstances combined to delay the publication, chief among them being what seemed to me a manifest impropriety in printing the results derived from photographs and measurements made by Mr. Rutherfurd, and by his own methods, before some account of these methods should have been published by him. His communication on the subject had been made to the National Academy immediately previous to my own, but was not yet in such form as he desired for publication.

The result showed a very remarkable accordance with Bessel's determination for 1840, although the total amount of relative proper motion during the elapsed 26 years, was comprised in the differences.

This memoir still remains in its original form, but unpublished; the results being deduced from 24 photographic impressions.

In the next year, 1868, I had the gratification of receiving from Mr. Rutherfurd the results of his measurements of 32 stars of the cluster Præsepe, derived from 11 impressions. These were computed in the same way that those of the Pleiades had been, and an analogous memoir upon this cluster was prepared for the National Academy.

Before leaving the country, early in 1870, I gave these two memoirs to Mr. Rutherfurd, with the request that he would send them to the printer at the same time with his own paper, already mentioned; but not before that. The condition of his health prevented him from attending to the matter for some time; and in the interval, he arrived at the unpleasant discovery that the screw of his micrometer had suffered from wear, and to an extent which led him to fear a want of that accuracy of which the method is susceptible, and which he hoped to see demonstrated by its very first applications.

Notwithstanding this possible blemish, it seems to me that the results ought to be now made public in their original form, after due mention of the circumstances; and it is among my hopes to be able soon to publish these two memoirs from the original manuscript of so many years ago.

The method was received with manifest distrust and disregard abroad; and, as was but natural for so essential a deviation from former methods, very many grounds of criticism and objection were brought up. One of the principal of these was the possible distortion of the collodion film, after receiving the impressions and before the measurements; but Mr. Rutherfurd speedily disposed of this point, at least so far as the albuminized plates are concerned; and, moreover, the combination of measurements of the same stars, derived from various plates, will at once make manifest the degree of confidence to which the several values and their mean are respectively entitled.

A far more serious obstacle to accuracy is presented by the difficulty of obtaining absolutely round images. Irregularity of form in the dots formed by the stellar impressions is almost incompatible with precision of measurement; and, as the time of exposure must often be long, the chief problem was, not so much to obtain the images as to insure uniformity of motion in the telescope during the period of exposure. Not that the photographic processes were not troublesome enough before the introduction of the dry-plate processes, for very great care and numerous precautions were often necessary to prevent the plates from drying too fast; but far the greatest difficulty consisted in obtaining sufficient precision in the clockwork and equatorial motion of the telescope.

It may easily be imagined how great was my desire, when leaving home for South America, to extend this new method of observation to the Southern hemisphere. But the obstacles encountered in the endeavor cannot be easily imagined. Upon these I will not enlarge here further than by saying that, in Cordoba, also, the attainment of circular dots for the star-images offered incomparably the greatest of all the difficulties of a practical character. The time of exposure was limited by the maximum size allowable for the large stars; and, previous to 1878, also by the drying of the plate, although exposures of twenty minutes were not unusual. Nevertheless, by dint of specially constructed governors and regulators, and by ceaseless attention, we did succeed in obtaining impressions which, to the unaided eye, appear absolutely round.

This necessity of long-continued and minute uniformity in the motion of the telescope, is, of course, largely diminished by the employment of instruments of large aperture, inasmuch as the necessary time of exposure is diminished in the same ratio in which the amount of light is increased. It is yet further and most notably diminished by the manifold greater sensitiveness of the dry gelatine plates. But notwithstanding all this, the attainment of round images, while almost indispensable for giving to stellar photography that increased accuracy to which it may lay claim as a means of research in practical astronomy, still demands especial care and precaution.

The Argentine Government cordially afforded every assistance which I deemed it proper to ask for these investigations. And although the chief energies of the Cordoba Observatory were absorbed by those investigations for which the institution was established, I had the satisfaction of obtaining a sufficient number of stellar photographs to occupy not only my own life-time, but many more, in their measurement and proper computation.

We photographed no northern stars there except the Pleiades and the Præsepe. Of the Pleiades I brought home sixteen plates, with two impressions of the whole group upon each, made in five different years, from 1872 to 1882, inclusive. Although the center of the cluster never attains a greater altitude at Cordoba than 34° 50′, some of the plates contain 70 stars. All but one of Bessel's stars are there, which belong within the limits of the field, the missing one being of the magnitude 9½, and there are yet other stars of the magnitudes 10, 10½, and 11. Of the Præsepe, there are five plates, and with a correspondingly increased number of stars.

About seventy southern clusters have been repeatedly photographed at Cordoba, comprising all those of the southern hemisphere which seemed important; also somewhat more than a hundred double stars, being a sufficient number to serve as a good test of the method. The total number of photographs now on hand is somewhat less than 1,300, only a few having been preserved in which the images were not circular.

Especial attention, however, was given, for many years, to taking frequent impressions, at the proper seasons, of four stars selected, on account of their large proper motion, as likely to manifest appreciable annual parallaxes. The refined and elaborate observations of Drs. Gill and Elkin, at Cape Town, have been made, computed, and published, while the Cordoba photographs have lain untouched in their boxes. There is but one of my four stars, β Hydri, which is not included in their list. Still it will be a matter of much interest to apply the photographic investigation to the same problem, even if for no other purpose than a comparison of the results of the two methods.

I am convinced that the Cordoba plates contain a large number of stars as faint as the eleventh magnitude of Argelander's scale, and believe that these are much the earliest photographs of stars fainter than Mr. Rutherfurd's of 1865 and 1866. There are several plates, covering about a degree square, which cannot contain less than 550 stars, and I believe that some of them contain a greater number. Such are those of the cluster Lac. 4,375 and that near x Carinæ.

The region in the vicinity of η Carinæ, and that magnificent tract in Sagittarius which is too densely sown with stars to be considered merely a portion of the Milky Way, and yet too large and undefined to be regarded simply as a cluster, were both of them taken several times, during the years 1875 to 1882, in series of overlapping photographs, each containing about a square degree, and recorded upon a glass surface of 9 by 12^{cm}. In their present form they are of course of small value for scientific use, inasmuch as the stars are too crowded for their configurations to be easily perceived; and, although these two series form in fact maps of considerable regions in the sky, still the record is of a very perishable nature, and of small avail for use by astronomers until it shall have been translated into an enduring and numerical form by micrometric measurement.

In this connection I may say that one of the greatest of my present anxieties regarding the Cordoba photographs arises from a discovery of the ease with which the collodion or gelatine film may become detached from the glass. The Argentine Government has assigned a moderate sum for the prosecution of the measurements, and with this some progress has already been made. It is but right to add that the full amount was given for which I asked. Still it is now quite inadequate, in consequence of the unfortunate depreciation of the national currency; and, in the present financial crisis there, I cannot reasonably expect more. Yet this matter of prompt measurements appears to me at present much more important than it did while I was unaware of the facility with which the film can blister and peel.

In 1883, after Mr. Common's brilliant success in photographing nebulas with his great three-foot reflector, he proposed to me a joint arrangement for photographing the whole heavens. My work at Cordoba was so near its close that it was out of the question to undertake anything new; but the immense labor requisite for the measurement of the plates would, under any circumstances, have tended to deter me. It is an undertaking demanding the joint energy, application, and material resources of a large number of persons, if the results are to be made available for astronomical use; indeed, I see no other astronomical value in the unmeasured photographs than the possibility of confirming at some future epoch the existence of relative motion previously detected or made probable by some other investigation.

Since then, the process of photographic charting is said to have been systematically undertaken by the Brothers Henry, at Paris. I have seen none of their plates; but their sharpness is highly spoken of, and the work appears to be prosecuted with much skill and very sensitive plates. There can of course be no question as to the value of any permanent record whatsoever, corresponding to a known date; yet I cannot feel that an essential advance is likely to be made in this way until the photographic record shall have been brought within the range of numerical expression.

The measurements of the Cordoba photographs, thus far completed, are those of the double stars, the four stars with large proper motion, of the Pleiades, of the Præsepe, and of the clusters Lac. 4,375 and Kappa Crucis. The corresponding computations have been made, as yet, only for a portion of the Pleiades impressions, but I am hopeful of completing all these at a comparatively early date. We shall then be able not only to compare the results with Bessel's of 45 years ago, but to test the deduced values of the proper motions by means of the photographic determinations of 1865 and 1866. Meanwhile the valuable memoir of Wolf has been published, giving closely approximate positions for 571 stars of the group, and Dr. Elkin has recently been executing at New Haven a heliometric triangulation of the principal stars. Our photographic results will have to be confronted with his delicate heliometric ones; and should they bear this test with tolerable success, it will be all that can reasonably be desired.

ART. XLIV.—*Lucasite, a new variety of Vermiculite*;* by THOMAS M. CHATARD.

IN the course of an examination of the minerals occurring with corundum at Corundum Hill, Macon Co., N. C., a vermiculite has been found which appears to be a distinct variety of this group. The name Lucasite has been given to it in honor of Dr. H. S. Lucas, so well known in connection with the discovery of the Chester, Mass., emery mine and with corundum mining in the South. To him I am indebted for many facilities and much valuable information.

The specimen from which the material examined was taken was found by me *in situ* in a corundum vein, and is a mass of a yellowish brown, small foliated mineral, through the central part of which runs an irregular seam of a fine granular, grass-green mineral, shown by analysis to be actinolite, intermixed with a small quantity of chromite and a large proportion of the vermiculite scales, which are however much smaller than those of the outer portions. The separation was made by means of Thoulet's solution, the specific gravity of the actinolite being 3·062, while that of the Lucasite is 2·613 (in water 25·5°). General characteristics as follows:

Foliated, compact, also disseminated; folia generally small, not over 2$^{\text{mm}}$ across. Cleavage basal, eminent. Color, yellowish-brown, the thinnest scales being almost colorless with

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* From a paper on "Gneiss-Dunyte Contacts," in the forthcoming Bulletin of the Division of Chemistry, U. S. Geol. Survey, 1885–86. Communicated by permission of the Director.

a greenish tint. Luster submetallic, somewhat greasy, the material having a great resemblance to the so-called "bronze-powder." Easily decomposed by concentrated hydrochloric acid, the silicic acid separating in pearly scales. When heated gives off much water and exfoliates with considerable force, particles being projected several centimeters from the mass, which doubles its bulk and becomes reddish brown with a silvery luster. It was examined microscopically by Mr. J. S. Diller, who reports "that it is biaxial and negative, but the angle between the optic axes, as seen in a cleavage plate split off parallel to the base, is uniformly small. Upon rotating the section, although the cross is plainly distorted into two hyperbolæ, they do not completely separate from each other."

In the following water determination the figures in brackets represent differences, the others being direct determinations:

					Average.
H_2O at 110°	3·87	3·81	3·72	3·72	3·78
H_2O at 130°	0·12	---	---	---	---
H_2O at red heat (blast lamp)	(6·83)	7·04	(6·95)	(7·00)	6·98
	10·82	(10·85)	10·67	10·72	10·76

Of the following analyses Nos. 1 and 2 are the results obtained on the air-dried mineral; No. 3 is the average and No. 4 the average calculated as dried at 110.°

	1.		2.	3.	4.
H_2O at 110°	3·78		(3·78)	3·78	----
H_2O at 130° and r. h.	6·98		(6·98)	6·98	7·22
SiO_2	39·89		39·74	39·81	41·17
Al_2O_3	12·88	=18·82	----	12·99	13·43
Cr_2O_3	0·54		19·04	0·54	0·56
Fe_2O_3	5·29			5·29	5·47
FeO	0·11		....	0·11	0·11
MnO	0·05		0·05	0·05	0·05
CaO	0·14		0·13	0·14	0·14
MgO	24·88		24·78	24·83	25·68
K_2O	5·76		(5·76)	5·76	5·96
Na_2O	0·20		(0·20)	0·20	0·21
	100·50		100·46	100·48	100·00

No. 4 gives the atomic ratio

$$\overset{\cdot\cdot\cdot\cdot}{\mathrm{Si}} : \overset{\cdot\cdot\cdot}{\bar{\mathrm{R}}} : \dot{\mathrm{R}} : \dot{\bar{\mathrm{R}}} : \dot{\bar{\mathrm{H}}}$$

$$2{\cdot}75 : \underbrace{1{\cdot}03 : 1{\cdot}29 : 0{\cdot}14} : 0{\cdot}80$$

$$2{\cdot}75 : 2{\cdot}46 : 0{\cdot}80$$

$${\cdot}7 : {\cdot}6 : {\cdot}2$$

The following table from Professor Cooke's paper* will show the relation of Lucasite to the other members of this group, all being taken as dried at 100° :

	$\ddot{\ddot{\mathrm{Si}}}$:	$\underbrace{\dddot{\bar{\mathrm{R}}} : \dot{\mathrm{R}} : \ddot{\bar{\mathrm{R}}}}$	: $\dot{\bar{\mathrm{H}}}$		
Hallite	2·42 :	2·41	: 1·47	or 8 : 8 : 5	or : 32 : 32 : 20
"Lerni"	2·54 :	2·50	: 1·30	" 2 : 2 : 1	" : 40 : 40 : 20
Pelhamite	2·75 :	2·46	: 1·26	" 9 : 8 : 4	" : 45 : 40 : 20
Culsageeite	2·50 :	2·66	: 1·23	" 2 : 2 : 1	" : 40 : 40 : 20
Jefferisite	2·56 :	2·53	: 1·17	" 9 : 9 : 4	" : 45 : 45 : 20
"Milbury"	2·38 :	2·74	: 1·14	" 8 : 9 : 4	" : 40 : 45 : 20
Lucasite	2·75 :	2·46	: 0·80	" 7 : 6 : 2	" : 70 : 60 : 20

Any attempt to deduce formulas for these minerals gives complicated results, and it is evident that we are dealing with a class of minerals of very similar physical properties but of widely varying compositions. That they are in all cases decomposition products of other minerals is very doubtful, for when the mode of occurrence of these minerals is carefully examined, it is difficult to resist the conclusion that in many cases they are as original in their formation as the chlorites and biotites and are not derived from them. The number of these varieties is already formidable and is constantly being added to, and it is much to be desired that a careful comparison of the whole series shall be made, so as to reduce the number of mineral names and to bring the survivors into a scientific arrangement.

Art. XLV.—*Crystallographic Notes*; by W. G. Brown.

Artificial Copper Crystals.

On taking apart to cleanse and put away a cell of a Calland gravity battery, which after using had been put aside and remained undisturbed for two or three months, there was found attached to the insulated wire coming from the copper plate, at the point where it passed the zinc plate, a pendant mass consisting almost entirely of copper crystals. At the place where these crystals were formed, the gutta percha of the insulated wire had been abraded and had come into contact with the zinc plate. The crystals were quite firmly attached to the insulated copper wire, and were also in contact with, but not adherent to, the zinc plate. At the time the crystals were found, the solution in the cell had evaporated to such an extent that about half the deposited crystals were out of the solution, and the zinc plate just touched it.

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* Cooke, Proc. Am. Acad., 1875, p. 461.

The crystals were in all probability accidentally formed by electrolysis, a method used by Golding Bird (and before him*), who obtained by means of a modified Daniell cell crystals of copper mixed with crystals of cuprite, a like result to that in the present occurrence, but of the forms present he makes no mention. Kossmann† mentions some electrolytic copper which had the appearance of hexagonal crystals, but were in reality twins, twinning plane the octahedral plane, and cutting each other at angles of 60° and 120°.

The crystals, found under the circumstances described in this note, are in the form of a mass of stout stalactites, with a drusy surface, about 30^{mm} long by 25^{mm} by 15^{mm} and weigh nearly 20 grams.

The upper part of the mass, that first deposited in contact with the zinc, consists of spongy dendritic copper of a loose filamentous texture, of a generally dull chocolate-red color with a metallic sheen. This portion possesses little coherence, readily separates into threads, and is very friable.

Forming a concentric layer round this upper portion are crystals of cuprous oxide (cuprite) mixed with distinctly crystallized compact copper, which forms the outer layer.

The lower and larger portion of the mass consists of definite copper crystals possessing its ordinary color and luster. The forms of the crystal facets, these not exceeding $\cdot 2^{mm}$ at their greatest breadth, cannot be made out without the use of a magnifying glass. When examined in this way the forms present are seen to be those of the octahedron and cube; usually the octahedron alone, but at times with its solid angles replaced by cubic planes. Rarely the cube with the solid angles replaced by the faces of the octahedron elongated into an apparently square prism. Doubtful is the octahedron as a right rhombic prism terminated by a dome, and the rhombic dodecahedron appearing as a hexagonal prism terminated by a rhombohedron. With these are other forms, apparently those of a hexagonal pyramid, due, however, to twinning. By far the greater number of crystals are twins, either according to the spinel law, twinning plane an octahedral face, or the twinning plane that of a trapezohedron forming polysynthetic twins. The most frequent form is one which appears to be a combination of a pentagonal dodecahedron and octahedron, as in pyrite, but this is probably a twin composed of five individuals, the form being that figured by A. von Lasaulx in his paper, "Ueber Zwillingskrystalle von gediegen Kupfer."‡ In many of these crystals four of the components are nearly equally developed,

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* See his paper, Phil. Trans., 1837, p. 37.

† Abstract in Chemisches Centralblatt, xvii, 432, 1886.

‡ Zeitschrift für Krystallographie und Mineralogie, viii, 302, fig. 6.

while the fifth is much smaller and its position is such as to show the reëntering angles markedly. Some of the crystals consist of six individuals like fig. 5 in the paper cited, or more like fig. 2 in a paper by Strüver, "Ueber polysynthetische Spinellzwillinge."* Other forms still more complex resemble those of spinel figured in the paper of Strüver referred to.

Artificial crystallized cuprous oxide (Cuprite).

On the outside of the spongy portion of the metallic copper just described there is a more or less continuous purple layer of crystals of cuprous oxide (cuprite). These are individually of a dark ruby-red color, with adamantine to sub-metallic luster.

The forms present are combinations of octahedron and cube in all stages from dominant octahedron to dominant cube. No simple forms were found. These crystals seem to have been formed just when the solution in the cell had evaporated to the level of the top of the deposited copper. They are confined to a very narrow layer near the outside of the dendritic copper, and are not pseudomorphs of the metallic copper, none of the crystals being twinned or in any way resembling in habit those of the metal among which they are found.

Another example of crystallized cuprous oxide (cuprite) was found on a camp spoon picked up near the site of a reserve magazine on Morris Island, South Carolina, constructed by the Federal forces when attacking Battery Wagner, entrance to Charleston harbor, S. C., in 1863. The spoon is of german silver, tarnished dull red and bronze, having spots of a green salt of copper (silicate ?) over its surface where small cemented groups and sprinkled grains of sand are firmly attached. Upon the surface of the spoon there are several blisters. Upon opening some of these, that part of the spoon beneath the blister is seen covered with brilliant transparent crystals of cuprous oxide (cuprite), showing only the faces of the octahedron, whose triangular shape can just be distinguished by the unaided eye. With a pocket lens they are distinctly visible.

While there is nothing new in the formation of these crystals on an alloy of copper, the short time in which the crystals have formed seems a noteworthy feature of this occurrence. The spoon could not have been exposed but little more than twenty years, from 1863 to 1886. In all cases mentioned in the books† the articles seem to have been exposed for a very long time to natural agencies, and lead to the conclusion that the formation, for example, on antique bronzes, under special conditions, is a

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* Zeitschrift für Krystallographie und Mineralogie, Band ii, p. 480, and Taf. XVII, fig. 2.

† For methods of production and occurrence, see Fouqué et Levy, Synthèse des Minéraux et des Roches, p. 378, and Fuchs Die künstlich dargestellten Mineralien, p. 68.

work of centuries. It may be that the composition of the alloy, german silver, had something to do with the comparative rapidity of production, aided perhaps by the salt water of the sea.

Crystallized Lead carbonate (*Cerussite*).

On the sand near the same locality at which the crystallized cuprous oxide was found, Morris Island, S. C., among the metallic remains of ammunition boxes, wagons, pieces of shell, the *débris* of a battle-field, a dozen Minié balls were picked up.

The greater number of the balls had, upon various parts of the surface patches, of lead carbonate, sometimes amorphous, sometimes acicular, crystalline and transparent, in some places 1^{mm} thick. It was seen, however, that more was present in the cup and about the base of the ball than elsewhere. The balls had not been fired, and were probably dropped attached to the cartridge, and it is possible that the formation of the carbonate was hastened by the rapid oxidation of the lead by the nitre of the gunpowder of the cartridge in the presence of moisture.

The Citadel, S. C. M. A., Charleston, S. C., Aug. 17, 1886.

ART. XLVI.—*On the chemical composition of Ralstonite*; by S. L. PENFIELD and D. N. HARPER.

A NUMBER of years ago Professor Geo. J. Brush generously gave one of us a specimen containing a large amount of the rare mineral ralstonite associated with thomsenolite from Arksut Fiord, Greenland. Considerable time was spent in picking out the octahedral crystals free from thomsenolite and only a partial analysis was made which was never published; difficulty was found in determining the fluorine, and the material was exhausted before a complete analysis was made. The results were essentially the same as those of Nordenskiöld.* Since then J. Brandl† has analyzed the mineral, using material which was selected by Professor P. Groth. The results of the three analyses are as follows:

	Nordenskiöld.	Penfield.	Brandl.
Mg	5·52	4·29	3·56
Na	5·66	4·12	5·50
K	*tr.*	·11	----
Ca	1·99	1·67	1·53
Al	22·94	22·33	22·14
H_2O	14·84	18·41	10·00
F	----	----	57·12
	49·95		99·85

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* Geol. Fören. i Stockholm. Förhandl., 1874, ii, 81.

† Annalen der Chemie, ccxiii, 7.

Only small quantities were used in making the above analyses owing to the scarcity of material and the difficulty of obtaining it free from thomsenolite. As far as the metals are concerned the three analyses agree remarkably well with one another. Nordenskiöld calculated that the 50·05 per cent of material which was not determined in his analysis, if assumed to be fluorine would not be sufficient to satisfy all the metals, and concludes that the mineral must contain some oxygen. The same would be true in Penfield's analysis. Brandl determined the fluorine directly and found it just sufficient to satisfy the metals; he proposed the formula $3(Na_2MgCa)F_2$, $8AlF_3$, $6H_2O$.

The fragments which were left after selecting material for the above analysis by Penfield were carefully saved, and although we could see that they contained large quantities of ralstonite, still it was found impossible to separate the pure mineral from thomsenolite by hand picking. After selecting the purest crystal of ralstonite we could find, we took its specific gravity by just floating it in the Thoulet solution and found it to be 2·560; by the same method we found the specific gravity of cryolite to be 2·974 and thomsenolite 2·979. The great difference in specific gravity between ralstonite and the other two minerals admits of a very perfect separation by means of the Thoulet solution. All the material which we had was crushed and made to pass an eighty-mesh sieve, the finest dust was washed away by means of water and the separation carried on as usual, repeating it several times so as to remove the last traces of thomsenolite. Finally, the purest powder was floated on a solution whose specific gravity was 2·611, a few heavier particles were removed and the solution diluted to the specific gravity 2·551, when all but a trace of the powder sank to the bottom. This material, amounting to over twelve grams, showed no impurity of double refracting thomsenolite when examined under the polarizing microscope, and was used in making the following analysis.

A few remarks are necessary regarding the method of analysis. It was found to be practically impossible to decompose the mineral completely with sulphuric acid; a residue was always left which could not be dissolved by further treatment with sulphuric acid, nor with hydrochloric or nitric acids. For the determination of the metals the mineral was fused with sodium carbonate, the fusion soaked out with water, sulphuric acid was added, and the solution evaporated and ignited till the hydrofluoric and excess of sulphuric acids were expelled. The mass was then dissolved in water and the metals determined according to the usual methods. Sodium was determined once by Smith's fusion method, and again by decomposing the mineral as far as possible with sulphuric acid, assuming that the sodium was all in solution and the insoluble portion some compound of aluminum. Water was determined by igniting the mineral in a combustion tube, passing the vapor over dry sodium carbonate and collecting it in a weighed chloride of calcium tube. The fluorine could not be determined by driving off the silicon fluoride. About twenty-five per cent of fluorine was readily driven off; by continuing the decomposition with the temperature of the sulphuric acid about 160°, silicon fluoride was slowly, but, in the course of six or eight hours never completely given off. The greatest amount of fluorine which we were able to drive over by this method was about thirty-one per cent. This is not at all in accordance with the statement of Brandl,* who states that the decomposition commences at 145° and is completed at 160°. We found it impossible to make a determination according to the method described by him. Our determinations are made according to the Berzelius method by fusing with mixed potassium and sodium carbonates and silica. They are probably too low by about one-half to one per cent, judging from test experiments which we made on cryolite. Our determinations are as follows:

			Mean.	Ratio.		
Mg	4·46	4·31	4·39	·183	·278	1·00
Na	4·25	4·27	4·27÷46	·093		
K	·12	·12	·12÷78	·002		
Ca	·03	---	·03			
Al	24·23	24·27	24·25		·882	3·17
F	39·76	40·05	39·91		2·101	7·56
H_2O	18·72	18·74	18·73			
			91·70			

The ratio of $(MgNa_2K_2):Al=1:3$ nearly. This ratio being assumed as correct, the ratio of the fluorine necessary to unite with the metals should be 11, whereas we only find 7·56. The fluorine is therefore not sufficient to unite with the metals and this is fully in accordance with the suggestion of Nordenskiöld. If the metals in our analysis, which are in excess of the fluorine, are united to hydroxyl, which, as has been shown to be the case in several instances, is capable of replacing fluorine, it would be necessary, in order to make the ratio $(Mg, Na_2, K_2):Al:(F+OH)=1:3:11$, to have 16·27 per cent of hydroxyl corresponding to 8·61 per cent of water; the remaining 10·12 per cent of water would then be regarded as water of crystallization, and would correspond to two molecules, making the formula of the mineral $(Mg, Na_2)Al_3(F+OH)_{11}.2H_2O$. Making this disposition of the water, our analysis would be:

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* Loc. cit.

		Ratio.		
Mg	4·39	·183	·278	1·00
Na	4·27	·093		
K	·12	·002		
Ca	·03			
Al	24·25		·882	3·17
F	39·91	2·101	3·058	11·00
OH	16·27	·957		
H_2O	10·12		·562	2·02
	99·36			

It will be seen that the assumption that hydroxyl replaces fluorine not only makes up for the deficiency in the analysis but also leads to a very satisfactory ratio. This assumption is also well supported by actual experiment. When the mineral is cautiously heated in a closed glass tube at first neutral water, by stronger ignition acid water, is driven off. The first that comes off is undoubtedly water of crystallization, afterwards the hydroxyl is decomposed and fluorine comes off in combination with the hydrogen. By drying the air-dry powder at 100° C. there is a loss of only 0·10 per cent; by heating in an air bath to a temperature never exceeding 250° C. the mineral lost 10·37 per cent; the water goes out very slowly; the experiment was carried on for over a week, during the last three days of which the weight remained very constant. If this 10·37 per cent is regarded as water of crystallization, the remaining 8·36 per cent would correspond to 15·78 per cent of hydroxyl, which agree closely with the figures in our last analysis. The ratio of Mg : Na is almost exactly 1 : 1, there seems to be no simple ratio between F and OH. The excess of the aluminum in the analysis may be owing to some slight impurity. We have never seen perfectly transparent, glassy crystals of ralstonite, and their turbidity may be owing to some slight decomposition; if this is the case the alkalies would naturally be most readily removed, causing the aluminum to be too high. If our fluorine determination should be as much as one per cent too low, which is probably not the case, our results would not be materially changed. Using the actual water of crystallization and hydroxyl determinations and determining the fluorine by difference, we would have for the latter part of our analysis:

		Ratio.		
F	40·79	2·147	3·075÷278	11·06
OH	15·78	·928		
H_2O	10·37		·576÷278	2·07

Probably this determination of fluorine by difference 40·79 per cent represents the true amount of that element more closely than the results of our actual determinations.

Assuming, as it seems fair to do, that our results and conclusions are correct and that the formula which we have proposed is the true one, namely, that the mineral is an isomorphous mixture of $(MgNa_2)Al_3F_{11}$, $2H_2O$ and $(MgNa_2)Al_3(OH)_{11}$, $2H_2O$, in which formulæ fluorine and hydroxyl play the same part or are isomorphous, let us see if we can in any way account for the variations in the previously published analyses, especially between Brandl's and our own, the only two complete analyses. First, we would emphasize that the greatest care was used in preparing the material for our analysis; the extremes in the specific gravity of the powder which we separated were 2·611 and 2·551, or a variation between the lightest and heaviest of only 0·060. Second, our analysis shows that our material is practically free from calcium, indicating a very complete separation from thomsenolite with which the ralstonite is so intimately associated, and showing that calcium is not an essential constituent of the mineral. Third, we were not limited regarding the amount of material which we could use, as we had an abundant supply of the pure mineral. From the same specimen from which our material was derived, one of us by very careful picking was able to obtain nearly one gram of octahedral crystals, which he supposed were pure but which, as is shown in the analysis near the beginning of this article, contained 1·67 per cent of calcium, showing that a most careful and laborious hand-picking had not been sufficient to free the small crystals wholly from thomsenolite from which the calcium was unquestionably derived. It seems highly probable that other investigators have worked with material containing slight quantities of thomsenolite. Groth,* for instance, states that the material which he furnished to Brandl for analysis, showed under the polarizing microscope particles of a strongly double refracting mineral with quadratic habit which was unquestionably thomsenolite. If we assume that the mineral is free from calcium as our analysis indicates and that the calcium in the other analyses is all derived from thomsenolite, we should find by calculation the following figures giving the per cent of thomsenolite in the analyzed material and of the mineral free from thomsenolite.

	Nordenskiöld.	Penfield.	Brandl.	Calculated from $(MgNa_2)Al_3F_{11}.2H_2O$
Thomsenolite	11·07	9·28	8·51	----
Mg	6·20	4·29	3·90	4·46
Na	3·95	4·27	5·05	4·27
Al	24·27	21·19	23·06	22·99
F	----		57·68	58·25
H_2O	15·68	19·46	10·17	10·03
			99·85	100·00
Ratio $(MgNa_2) : Al =$	1·17 : 3	1·06 : 3	0·97 : 3	

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* Zeitschr. Kryst., vii, 474.

In these analyses the ratio $(MgNa_2):Al=1:3$ very nearly, especially considering the small quantity of mineral which was used in making the analyses and in Brandl's analysis, the only complete one, the fluorine is just sufficient to satisfy the metals, while the ratio $(MgNa_2):Al:F:H_2O=0{\cdot}97:3:10{\cdot}88:2{\cdot}02$, or nearly $1:3:11:2$, the same as required by the formula proposed by us, only in this case the compound is a pure fluorine compound, containing no hydroxyl. Following Brandl's analysis we have given the percentage composition calculated from the above ratio in which the $Mg:Na=1:1$. It will be noticed how closely the figures agree with the analysis of Brandl.

The great difference in the proportion in which the metals are united, $(MgNa_2):Al=1:3$ in ralstonite and $Ca:Na:Al=1:1:1$ in thomsenolite, would account for the decided change in the formula derived from an analysis of a mixture of ralstonite with a little thomsenolite. Brandl's formula, $3(Na_2MgCa)F_2$, $8AlF_3$, $6H_2O$, is therefore a little too low in AlF_3. The difference in the deportment of the mineral when treated with strong sulphuric acid may be owing to the fact that although the fluorine compound is readily decomposed by that acid so that Brandl was able to determine the fluorine by driving over SiF_4, the hydroxyl compound in our mineral in some way hinders the decomposition of the fluorine compound, perhaps by being in itself with difficulty decomposed and inclosing and thus protecting some of the molecules of the fluorine compound from decomposition.

In thin sections under the microscope all of the ralstonite appears very transparent and free from visible inclusions and decomposition products. Some of the crystals on the original specimen were colored yellow and where one of these had been cut through, the yellow substance was seen to consist of a very thin film, probably of iron oxide, coating the crystal. The larger crystals were zonal in structure, the zones lying parallel to the faces of the octahedron. This zonal structure is scarcely perceptible in ordinary light, being indicated by faint greyish streaks running parallel to the contours of the cross section, which could not be resolved by the use of high powers into visible inclusions. In polarized light the zonal structure was more perceptible; all of the crystals show slight double refraction and a division of the cross sections into fields reminding one of the double refraction of analcite. The slightly double refracting ralstonite with its absence of cleavage is in marked contrast to the strongly double refracting thomsenolite, showing brilliant polarization colors, blue of the second order, distinct cleavage and inclined extinction.

In closing we wish to express our thanks to Professor Geo. J. Brush for his liberality in providing us with the rare material for carrying on this investigation.

Mineralogical Laboratory, Sheffield Scientific School, Oct. 12th, 1886.

ART. XLVII.—*Mineralogical Notes;* by EDWARD S. DANA.

1. *Columbite from Standish, Maine.*[*]

THE crystals of columbite obtained a few years since from Standish, Maine, largely through the active efforts of Professor O. D. Allen, are well known for their brilliant luster and perfection of form. In these respects they are far superior to those from any other known locality. This fact has made it seem worth while to attempt a more exact determination of the crystalline elements than has been hitherto possible. The material in hand consisted of a large suite of crystals belonging to the Yale College cabinet and that of Professor Brush, and also a number of fine specimens kindly loaned for the purpose by Dr. George H. Williams of the Johns Hopkins University in Baltimore.

The true form of the species was first established by J. D. Dana, fifty years since, and the axial ratio was determined by him on a crystal from Middletown with considerable exactness. In 1861 Schrauf published his monograph of the species and in it gave a new value of the axes upon the basis of measurements of crystals from Greenland and Bodenmais. He also adopted another fundamental form, making *u* (133 Dana) the unit pyramid. Schrauf's axes have been accepted since that time, although a comparison of his measured and calculated angles shows that the material he worked upon was not suited to give very accurate results.

Among the crystals from Standish a few were found allowing of exact measurement and the angles obtained from the best one of these are given in the following table:

	Calculated.	Measured.
$530 : 5\bar{3}0$	52° 52′	52° 42′
$\bar{5}30 : \bar{5}\bar{3}0$		52 53
$530 : \bar{5}30$	127 8	127 9
$5\bar{3}0 : \bar{5}\bar{3}0$		127 14
$110 : 1\bar{1}0$	79 17	79 14
$\bar{1}10 : \bar{1}\bar{1}0$		79 18
$110 : \bar{1}10$	100 43	100 45
$1\bar{1}0 : \bar{1}\bar{1}0$		100 43
$130 : 1\bar{3}0$	136 10	*136 10
$\bar{1}30 : \bar{1}\bar{3}0$		130 10
$130 : \bar{1}30$	43 50	43 51
$1\bar{3}0 : \bar{1}\bar{3}0$		43 49
$001 : 021$	60 40	60 41
$021 : 0\bar{2}1$	121 20	——
$001 : 103$	19 42	——
$111 : \bar{1}\bar{1}1$	108 43	*108 43
$1\bar{1}1 : \bar{1}11$		108 42
$111 : 1\bar{1}1$	62° 28′	62° 20′
$\bar{1}11 : \bar{1}\bar{1}1$		62 29
$111 : \bar{1}11$	77 29	77 23
$1\bar{1}1 : \bar{1}\bar{1}1$		77 36
$233 : \bar{2}33$	56 17	——
$133 : \bar{1}\bar{3}3$	87 36	——
$1\bar{3}3 : \bar{1}33$		
$133 : 1\bar{3}3$	79 54	——
$\bar{1}33 : \bar{1}\bar{3}3$		
$133 : \bar{1}33$	29 57	29 59
$\bar{1}33 : \bar{1}\bar{3}3$		
$163 : 1\bar{6}3$	118 20	118 19
$\bar{1}63 : \bar{1}\bar{6}3$		——
$163 : \bar{1}63$	19 54	19 59
$1\bar{6}3 : \bar{1}\bar{6}3$		20 0

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[*] Abstract of an article published in vol. xii of Groth's Zeitschrift für Krystallographie und Mineralogie.

As fundamental angles the following (indicated by an asterisk in the table) were accepted:

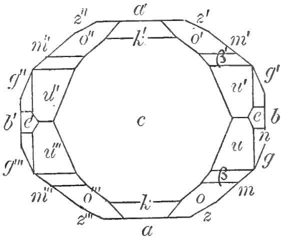
$$130 \wedge 1\bar{3}0 = 136^\circ\ 10' \quad \text{and} \quad 111 \wedge \bar{1}\bar{1}1 = 108^\circ\ 43'$$

The axial ratio deduced from these is given below, and the above table contains the calculated angles:

$\breve{a} : \bar{b} : c = 0{\cdot}82850 : 1 : 0{\cdot}88976$ (Dana's position).
$a : b : c = 0{\cdot}40234 : 1 : 0{\cdot}35798$ (Schrauf's position).

A comparison of the measured and calculated angles shows a very satisfactory agreement considering the character of the species and the results previously obtained. Measurements on a number of other less perfect crystals gave confirmatory results.

No reason was found for believing that there is any deviation from the orthorhombic form such as has been often suggested, and in fact it was proved that no deviation greater than two or three minutes could exist. Arzruni and Groth have shown on optical grounds that columbite is really orthorhombic. The axial ratio here deduced agrees much better with that of J. D. Dana (in fact the angles of the prismatic zone are nearly identical) than with that of Schrauf. The similarity in angles between the Middletown and Standish crystals goes to prove that the variation of form connected with the change of composition must be small. The Middletown columbite contains a large amount of iron tantalate (nearly 30 per cent), while the Standish mineral is nearly pure iron columbate (niobate) with the specific gravity $=5{\cdot}65$. As bearing in the same direction the writer found that the Northfield columbite, which is almost a tantalite (57 per cent Ta_2O_5, sp. grav. $=6{\cdot}8$), had also the habit and angles of ordinary columbite.

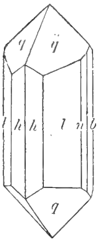


The crystals of columbite from Standish resemble those of Haddam and Middletown in habit, though occasionally they are short and stout, somewhat elongated in the direction of the $\breve{a}$ axis and hence approximate to the Greenland form. The accompanying figure is a basal projection of a common type. Twins are common and all after the usual law, the twinning plane the brachydome *e*. They are generally the familiar heart-shaped contact twins, but much variation in habit is observed. The observed planes on the Standish crystals are:

a (100, $i\text{-}\bar{\imath}$), *b* (010, $i\text{-}\breve{\imath}$), *c* (001, *O*), *z* (530, $i\text{-}\bar{\tfrac{5}{3}}$), *m* (110, *I*), *g* (130, $i\text{-}\breve{3}$), *l* (106, $\tfrac{1}{6}\text{-}\bar{\imath}$), *k* (103, $\tfrac{1}{3}\text{-}\bar{\imath}$), *e* (021, $2\text{-}\breve{\imath}$), *o* (111, 1), *β* (233, $1\text{-}\breve{\tfrac{3}{2}}$), *u* (133, $1\text{-}\breve{3}$), *n* (163, $2\text{-}\breve{6}$).

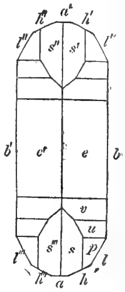
2. *Diaspore.*

Diaspore from Newlin, Penn.—Through the kindness of Professor F. W. Clarke and Mr. Joseph Willcox I have had the opportunity of examining a crystal of diaspore from Newlin, near Unionville, Penn., belonging to the latter. The crystal is the finest ever found at the locality; it is prismatic in habit, about $\frac{3}{8}$ inch in length and doubly terminated. It showed the following planes, the vertical zone being strongly striated: *b* (010, $i\text{-}\breve{i}$), *h* (210, $i\text{-}\bar{2}$), *l* (120, $i\text{-}\breve{2}$), *n* (150, $i\text{-}\breve{5}$), *q* (232, $\frac{3}{2}\text{-}\breve{\frac{3}{2}}$). Of these the pyramid *q* is new to the species; such measurements as were possible agreed with the calculated angles (accepting the axes of Kokscharow). Better measurements were obtained on a similar but very small crystal from the same locality in the cabinet of Professor Brush. These angles are:



	Calculated.	Measured.
$qq' = 232 \wedge \bar{2}32 =$	51° 2′	51° 20′
$qq'' = 232 \wedge \bar{2}\bar{3}2 =$	96° 3′	96° 14′
$qq''' = 232 \wedge 2\bar{3}2 =$	74° 34′	74° 30′

Diaspore from Chester, Mass.—The Chester diaspore commonly occurs in thin cleavage plates implanted upon the magnetite gangue. Occasionally it is found in very delicate acicular crystals, and again in groups of crystals tabular parallel to the brachypinacoid. A basal projection of the last named form is given in the accompanying figure. The crystals are in fact composite, consisting of parts in nearly parallel position. They are deeply striated in the vertical zone and also in the zone *pe*. The observed planes are:



a (100, $i\text{-}\bar{i}$), *b* (010, $i\text{-}\breve{i}$), *h* (210, $i\text{-}\bar{2}$), *l* (120, $i\text{-}\breve{2}$), *e* (011, $1\text{-}\breve{i}$), *s* (212, $1\text{-}\bar{2}$), *p* (111, 1), *u* (344, $1\text{-}\frac{4}{3}$), *v* (122, $1\text{-}\breve{2}$). Of these *u* and *v* are new, they are determined by the following measurements:

	Calculated.	Measured.
$au =$	67° 30′	67° 29′
$av =$	74° 35′	75° 30′ approx.

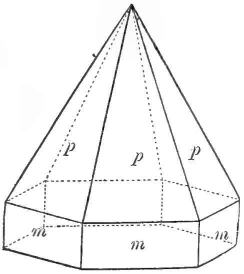
3. *Zincite.*

Our knowledge of the crystals of zinc protoxide has rested thus far upon observations of artificial crystals, the native mineral showing usually only massive forms with distinct basal and prismatic cleavage. Early measurements of the artificial crystals were given by Rose (in 1852), and since then contributions to the subject have been made by vom Rath, DesCloizeaux and others. The recent observations of Rinne (Jahrb. Min., 1884, ii, 164) appear to be highly accurate. He obtained as the pyramidal angle 52° 21′ and deduced as the vertical axis:

$$c = 1{\cdot}6219$$

His observations upon etching-figures and other related points are also of much interest.

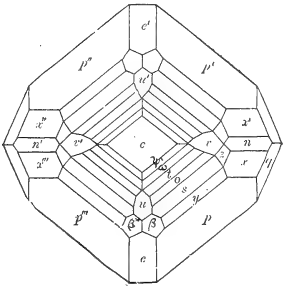
The cabinet of Mr. Clarence S. Bement contains several specimens of the zincite from Stirling Hill, N. J., which show distinct crystals. In two of these the acute quartzoid characteristic of the species is seen in hemimorphic development with the prism and basal plane at one extremity. Other specimens show the same form larger (up to two inches in length) in outline imbedded in the gangue. The accompanying figure gives the habit of the crystals, and the following angles, though making no claim to accuracy, show a fair agreement with the angles of the artificial forms.



	Measured.	Calculated.
pp' =	53° 43′	52° 21′ Rinne.
$p'p''$ =	54° 2′	
cp =	65° 20′ approx.	61° 54′

4. *Sulphur.*

A specimen of native sulphur from Rabbit Hollow, Nevada, in the cabinet of Professor Brush, is interesting because of the complexity of the form. The mass is crystalline throughout, the parts mostly in parallel position, though distinct isolated crystals are rare. One of these was detached and measured; it is shown in the figure in basal projection. The planes are:



c (001, *o*), *u* (103, $\frac{1}{3}$-$\bar{\imath}$), *e* (101, 1-$\bar{\imath}$), *v* (013, $\frac{1}{3}$-$\breve{\imath}$), *n* (011, 1-$\breve{\imath}$), *ψ* (119, $\frac{1}{9}$), *ω* (118, $\frac{1}{8}$), *t* (115, $\frac{1}{5}$), *o* (114, $\frac{1}{4}$), *s* (113, $\frac{1}{3}$), *y* (112, $\frac{1}{2}$), *p* (111, 1), *β* (315, $\frac{3}{5}$-$\bar{3}$), *z* (135, $\frac{3}{5}$-$\breve{3}$), *x* (133, 1-$\breve{3}$). Of these *β* and *o* are new; *β* was determined by the zones *p*, *s*‴ (111, 1$\bar{1}$3) and *y*, *x* (112, 133); also *o* lies in the zone *c*, *p* (001, 111).

The calculated angles of these forms (accepting the axes of Kokscharow) are:

	Calculated.	Measured.
$oo' = 315 \wedge 3\bar{1}5 = 24° 54'$ $co = 001 \wedge 114 =$	37° 2′	37° 1′

Other measured angles are:

	Calculated.	Measured.
$ct = 001 \wedge 115 =$	31° 6′	31° 9′
$cs = 001 \wedge 113 =$	45° 10′	45° 9′
$cy = 001 \wedge 112 =$	56° 28′	56° 26′
$cp = 001 \wedge 171 =$	71° 40′	71° 40′

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Geological Time. Address of Professor* G. H. Darwin *before the Mathematical and Physical Section of the British Association at Birmingham.*— . . . It will, I think, be useful to avail myself of the present occasion to direct your attention to a certain group of theories which are still in an undeveloped and somewhat discordant condition, but which must form the nucleus round which many observations have yet to be collected before these theories and their descendants can make a definitely accepted body of truth. If I am disposed to criticise some of them in their actual form, I shall not be understood as denying the great service which has been rendered to science by their formulation.

Great as have been the advances of geology during the present century, we have no precise knowledge of one of its fundamental units. The scale of time on which we must suppose geological history to be drawn is important not only for geology itself, but it has an intimate relation with some of the profoundest questions of biology, physics, and cosmogony.

We can hardly hope to obtain an accurate measure of time from pure geology, for the extent to which the events chronicled in strata were contemporaneous is not written in the strata themselves, and there are long intervals of time of which no record has been preserved.

An important step has been taken by Alfred Tylor, Croll, and others, towards the determination of the rate of action of geological agents. From estimates of the amount of sediment carried down by rivers, it appears that it takes from 1000 to 6000 years to remove one foot of rock from the general surface of a river basin.

From a consideration of the denuding power of rivers and a measurement of the thickness of stratified rock, Phillips has made an estimate of the period of time comprised in geological history, and finds that, from stratigraphical evidence alone, we may regard the antiquity of life on the earth as being possibly between 38 and 96 millions of years ("Life on the Earth," Rede Lecture, 1860).

Now while we should perhaps be wrong to pay much attention to these figures, yet at least we gain some insight into the order of magnitude of the periods with which we have to deal, and we may feel confident that a million years is not an infinitesimal fraction of the whole of geological time.

It is hardly to be hoped, however, that we shall ever attain to any very accurate knowledge of the geological time scale from this kind of argument.

But there is another theory which is precise in its estimate, and which, if acceptable from other points of view, will furnish exactly what is requisite. Mr. Croll claims to prove that great changes of climate must be brought about by astronomical events of which the dates are known or ascertainable ("Climate and Time"). The perturbation of the planets causes a secular variability in the eccentricity of the earth's orbit, and we are able confidently to compute the eccentricity of many thousands of years forward and backward from to-day, although it appears that, in the opinion of Newcomb and Adams, no great reliance can be placed on the values deduced from the formulæ at dates so remote as those of which Mr. Croll speaks. According to Mr. Croll, when the eccentricity of the earth's orbit is at its maximum, that hemisphere which has its winter in aphelion would undergo a glacial period. Now, as the date of great eccentricity is ascertainable, this would explain the great Ice Age and give us its date.

The theory has met with a cordial acceptance on many sides, probably to a great extent from the charm of the complete answer it affords to one of the great riddles of geology.

Adequate criticism of Mr. Croll's views is a matter of great difficulty on account of the diversity of causes which are said to coöperate in the glaciation. In the case of an effect arising from a number of causes, each of which contributes its share, it is obvious that if the amount of each cause and of each effect is largely conjectural, the uncertainty of the total result is by no means to be measured by the uncertainty of each item, but is enormously augmented. Without going far into details it may be said that these various concurrent causes result in one fundamental proposition with regard to climate, which must be regarded as the keystone of the whole argument. That proposition amounts to this—that climate is unstable.

Mr. Croll holds that the various causes of change of climate operate *inter se* in such a way as to augment their several efficiencies. Thus the trade-winds are driven by the difference of temperature between the frigid and torrid zones, and if from the astronomical cause the northern hemisphere becomes cooler the trade-winds on that hemisphere encroach on those of the other, and the part of the warm oceanic current which formerly flowed into the cold north zone, will be diverted into the southern hemisphere. Thus the cold of the northern hemisphere is augmented, and this in its turn displaces the trade-winds further, and this again acts on the ocean currents, and so on; and this is neither more nor less than instability.

But if climate be unstable, and if, from some of those temporary causes for which no reasons can as yet be assigned, there occurs a short period of cold, then surely some even infinitesimal portion of the second link in the chain of causation must exist; and this should proceed in the first case to augment the departure from the original condition, and the climate must change.

In a matter so complex as the weather, it is at least possible that there should be instability when the cause of disturbance is astronomical, whilst there is stability in an ordinary sense. If this is so, it might be explained by the necessity for a prolonged alteration in the direction of prevailing winds in order to affect oceanic currents (Zöppritz, *Phil. Mag.*, 1878).

However this may be, so remarkable a doctrine as the instability of climate must certainly be regarded with great suspicion, and we should require abundant proof before accepting it. Now there is one result of Mr. Croll's theory which should afford almost a crucial test of its acceptability. In consequence of the precession of the equinoxes the conditions producing glaciation in one hemisphere must be transferred to the other every 10,000 years. If there is good geological evidence that this has actually been the case, we should allow very great weight to the astronomical theory, notwithstanding the difficulties in its way. Mr. Croll has urged that there is such evidence, and this view has been recently strongly supported by M. Blytt (*Nature*, July 8 and 15, 1886). Other geologists do not, however, seem convinced of the conclusiveness of the evidence.

Thus Mr. Wallace ("Island Life"), whilst admitting that there was some amelioration of climate from time to time during the last glacial period, cannot agree in the regular alternations of cold and warm demanded by Mr. Croll's theory. To meet this difficulty he proposes a modification. According to his view, large eccentricity in the earth's orbit will only produce glaciation when accompanied by favorable geographical conditions. And when extreme glaciation has once been established in the hemisphere which has its winter in aphelion, the glaciation will persist, with some diminution of intensity, when precession has brought round the perihelion to the winter. In this case, according to Wallace, glaciation will be simultaneous on both hemispheres.

Again, he contends that, if the geographical conditions are not favorable, astronomical causes alone are not competent to produce glaciation.

There is agreement between the two theories in admitting instability of climate at first, when glaciation is about to begin under the influence of great eccentricity of the orbit, but afterwards Wallace demands great stability of climate. Thus he maintains that there is great stability in extreme climates, either warm or cold, while there is instability in moderate climates. I cannot perceive that we have much reason from physical considerations for accepting these remarkable propositions, and the acceptance or rejection of them demands an accurate knowledge of the most nicely balanced actions, of which we have as yet barely an outline.

Ocean currents play a most prominent part in these theories, but at this moment our knowledge of the principal oceanic circulation, and of its annual variability, is very meagre. In the course of a few years we may expect a considerable accession to our knowledge, when the Meteorological Office shall have completed a work but just begun—viz., the analysis of ships' logs for some sixty years, for the purpose of laying down in charts the oceanic currents.

With regard to the great atmospheric currents even the general scheme is not yet known. Nearly thirty years ago Professor James Thomson gave before this Association at Dublin an important suggestion on this point. As it has been passed over in complete silence ever since, the present seems to be a good opportunity of redirecting attention to it.

According to Halley's theory of atmospheric circulation, the hot air rises at the equator and floats north and south in two grand upper currents, and it then acquires a westward motion relatively to the earth's surface, in consequence of the earth's rotation. Also the cold air at the pole sinks and spreads out over the earth's surface in a southerly current, at first with a westerly tendency, because the air comes from the higher regions of the atmosphere, and afterwards due south, and then easterly, when it is left behind by the earth in its rotation.

Now Professor Thomson remarks that this theory disagrees with fact in as far as that in our latitudes, the winds, though westerly, have a poleward tendency, instead of the reverse.

In the face of this discrepancy he maintains that "the great circulation already described does actually occur, but occurs subject to this modification, that a thin stratum of air on the surface of the earth in the latitudes higher than 30°—a stratum in which the inhabitants of those latitudes have their existence, and of which the movements constitute the observed winds of those latitudes—being by friction and impulses on the surface of the earth, retarded with reference to the rapid whirl or vortex-motion from west to east of the great mass of air above it, tends to flow toward the pole, and actually does so flow to supply the partial void in the central parts of that vortex due to the centrifugal force of its revolution. Thus it appears that in the temperate latitudes there are three currents at different heights—that the uppermost moves toward the pole, and is part of a grand primary circulation between equatorial and polar regions; that the lowermost moves also toward the pole, but is only a thin stratum forming part of a secondary circulation; that the middle current moves from the pole, and constitutes the return current for both the preceding; and that all these three currents have a prevailing motion from west to east (Brit. Assoc. *Report*, Dublin, 1857, pp. 38, 39).

Such, then, appears to be our present state of ignorance of these great terrestrial actions, and any speculation as to the precise effect of changes in the annual distribution of the sun's heat must be very hazardous until we know more precisely the nature of the thing changed.

When looking at the astronomical theory of geological climate as a whole, one cannot but admire the symmetry and beauty of the scheme, and nourish a hope that it may be true; but the mental satisfaction derived from our survey must not blind us to the doubts and difficulties with which it is surrounded.

And now let us turn to some other theories bearing on this important point of geological time.

Amongst the many transcendent services rendered to science by Sir William Thomson, it is not the least that he has turned the searching light of the theory of energy on to the science of geology. Geologists have thus been taught that the truth must lie between the cataclysms of the old geologists and the uniformitarianism of forty years ago. It is now generally believed that we must look for a greater intensity of geologic action in the remote past, and that the duration of the geologic ages, however little we may be able mentally to grasp their greatness, must bear about the same relation to the numbers which were written down in the older treatises on theology, as the life of an ordinary man does to the age of Methuselah.

The arguments which Sir William Thomson has adduced in limitation of geological time are of three kinds. I shall refer first to that which has been called the argument from tidal friction; but before stating the argument itself it will be convenient to speak of the data on which the numerical results are based.

Since water is not frictionless, tidal oscillations must be subject to friction, and this is evidenced by the delay of twenty-four to thirty-six hours which is found to occur between full and change of moon and spring-tide. An inevitable result of this friction is that the diurnal rotation of the earth must be slowly retarded, and that we who accept the earth as our timekeeper must accuse the moon of a secular acceleration of her motion round the earth, which cannot be otherwise explained. It is generally admitted by astronomers that there actually is such an unexplained secular acceleration of the moon's mean motion.

No passage in Thomson and Tait's "Natural Philosophy" has excited more general interest than that in which Adams is quoted as showing that, *with a certain value for the secular acceleration*, the earth must in a century fall behind a perfect chronometer, set and rated at the beginning of the century, by twenty-two seconds. Unfortunately this passage in the first edition gave an erroneous complexion to Adams's opinion, and being quoted without a statement of the premises, has been used in popular astronomy as an authority for establishing the statement that the earth is actually a false timekeeper to the precise amount specified.

In the second edition (in the editing of which I took part) this passage has been rewritten, and it is shown that Newcomb's estimate of the secular acceleration gives only about one-third of the retardation of the earth's rotation, which resulted from Adams's value. The last sentence of the paragraph here runs as follows: "It is proper to add that Adams lays but little stress on the actual numerical values which have been used in this computation, and is of opinion that the amount of tidal retardation of the earth's rotation is quite uncertain." Thus, in the opinion of our great physical astronomer, a datum is still wanting for the determination of a limit to geological time, according to Thomson's argument.

However, subject to this uncertainty, with the values used by Adams in his computation, and with the assumption that the rate of tidal friction has remained constant, then a thousand million years ago the earth was rotating twice as fast as at present. In the last edition of "Natural Philosophy" the argument from these data runs thus:

"If the consolidation of the earth took place then or earlier, the ellipticity of the upper layers (of the earth's mass) must have been $\frac{1}{230}$ instead of about $\frac{1}{300}$, as it is at present. It must necessarily remain uncertain whether the earth would from time to time adjust itself completely to a figure of equilibrium adapted to the rotation. But it is clear that a want of complete adjustment would leave traces in preponderance of land in equatorial regions. The existence of large continents and the great effective rigidity of the earth's mass render it improbable that the adjustment, if any, to the appropriate figure of equilibrium would be complete. The fact, then, that the continents are arranged along meridians, rather than in an equatorial belt, affords some degree of proof that the consolidation of the earth took place at a time when the diurnal rotation differed but little from its present value. It is probable, therefore, that the date of consolidation is considerably more recent than a thousand million years ago."

I trust it may not be presumptuous in me to criticise the views of my great master, at whose intuitive perception of truth in physical questions I have often marvelled, but this passage does not even yet seem to me to allow a sufficiently large margin of uncertainty.

It will be observed that the argument reposes on our certainty that the earth possesses rigidity of such a kind as to prevent its accommodation to the figure and arrangement of density appropriate to its rotation. In an interesting discussion on subaërial denudation Croll has concluded that nearly one mile may have been worn off the equator during the past 12,000,000 years, if the rate of denudation all along the equator be equal to that of the basin of the Ganges ("Climate and Time," 1885, p. 336). Now, since the equatorial protuberance of the earth when the ellipticity is $\frac{1}{230}$ is fourteen miles greater than when it is $\frac{1}{300}$, it follows that 170,000,000 years would suffice to wear down the surface to the equilibrium figure. Now let these numbers be halved or largely reduced, and the conclusion remains that denudation would suffice to obliterate external evidence of some early excess of ellipticity.

If such external evidence be gone,* we must rely on the incompatibility of the known value of the precessional constant with an ellipticity of internal strata of equal density greater than that appropriate to the actual ellipticity of the surface. Might there not be a considerable excess of internal ellipticity without our being cognizant of the fact astronomically?

And, further, have we any right to feel so confident of the internal structure of the earth as to be able to allege that the earth would not through its whole mass adjust itself almost completely to the equilibrium figure?

Tresca has shown in his admirable memoirs on the flow of solids that when the stresses rise above a certain value the solid becomes plastic, and is brought into what he calls the state of fluidity. I do not know, however, that he determined at what stage the flow ceases when the stresses are gradually diminished. It seems probable, at least, that flow will continue with smaller stresses than were initially necessary to start it. But if this is so, then, when the earth has come to depart both internally and externally from the equilibrium condition, a flow of solid will set in, and will continue until a near approach to the equilibrium condition is attained.

When we consider the abundant geological evidence of the plasticity of rock, and of the repeated elevation and subsidence of large areas on the earth's surface, this view appears to me more probable than Sir William Thomson's.

On the whole, then, I can neither feel the cogency of the argument from tidal friction itself, nor, accepting it, can I place any reliance on the limits which it assigns to geological history.

The second argument concerning geological time is derived from the peculiar cooling of the earth.

We know in round numbers the rate of increase of temperature, or temperature gradient, in borings and mines, and the conductivity of rock. These data enable us to compute how long ago the surface must have had the temperature of melting rock, and when it must have been too hot for vegetable and animal life.

Sir William Thomson, in his celebrated essay on this subject (republished in Thomson and Tait's "Natural Philosophy," Appendix D), concludes from this argument that "for the last 96,000,000 million years the rate of increase of temperature underground has gradually diminished from about $\frac{1}{10}$th to about $\frac{1}{50}$th of a degree Fahrenheit per foot. . . . Is not this, on the whole, in harmony with geological evidence, rightly interpreted? Do not the vast masses of basalt, the general appearances of mountain-ranges, the violent distortions and fracture of strata, *the great*

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* I find by a rough calculation that $\frac{55}{150}$ths of the land in the northern hemisphere are in the equatorial half of that hemisphere, viz., between 0° and 30° N. lat.; and that $\frac{46}{55}$ths of the land in the southern hemisphere are in the equatorial half of that hemisphere, viz., between 0° and 30° S. lat. Thus for the whole earth, $\frac{101}{205}$ths of the land lie in the equatorial half of its surface, between 30° N. and S. lat. In this computation the Mediterranean, Caspian and Black Seas are treated as land.

prevalence of metamorphic action (which must have taken place at depths of not many miles, if so much), all agree in demonstrating that the rate of increase of temperature downwards must have been much more rapid, and in rendering it probable that volcanic energy, earthquake shocks, and every kind of so-called plutonic action, have been, on the whole, more abundantly and violently operative in geological antiquity than in the present age?"

Now, while I entirely agree with the general conclusion of Sir William Thomson, it is not unimportant to indicate a possible flaw in the argument. The flaw will only be acknowledged as possible by those who agree with the previous criticism on the argument from tidal friction.

The present argument as to the date of the consolidation of the earth reposes on the hypothesis that the earth is simply a cooling globe, and there are reasons why this may not be the case. The solidification of the earth probably began from the middle and spread to the surface. Now is it not possible, if not probable, that, after a firm crust had been formed, the upper portion still retained some degree of viscosity? If the interior be viscous, some tidal oscillations must take place in it, and, these being subject to friction, heat must be generated in the viscous portion; moreover the diurnal rotation of the earth must be retarded. Some years ago, in a paper on the tides of a spheroid, viscous throughout the whole mass (*Phil. Trans.*, part ii, 1879), I estimated the amount and distribution of the heat generated whilst the planet's rotation is being retarded and the satellite's distance is being increased. It then appeared that on that hypothesis the distribution of the heat must be such that it would only be possible to attribute a very small part of the observed temperature gradient to such a cause. Now, with a probable internal constitution for the earth in early times, the result might be very different. Suppose, in fact, that it is only those strata which are within some hundreds of miles of the surface which are viscous, whilst the central portion is rigid. Then, when tidal friction does its work the same amount of heat is generated as on the hypothesis of the viscosity of the whole planet, but instead of being distributed throughout the whole mass, and principally towards the middle, it is now to be found in the more superficial layers.

In my paper it is shown that with Thomson's data for the conductivity of rock and the temperature gradient, the annual loss of heat by the earth is 1/260,000,000 part of the earth's kinetic energy of rotation.

Also, if by tidal friction the day is reduced from D_0 hours to D hours, and the moon's distance augmented from Π_0 to Π earth's radii, the energy which has been converted into heat in the process is $\left(\frac{D}{D_0}\right)^2 - 1 - 8{\cdot}84\left(\frac{1}{\Pi} - \frac{1}{\Pi_0}\right)$ times the earth's kinetic energy of rotation.

From these data it results that the heat generated in the lengthening of the day from twenty-three to twenty-four hours is equal to the amount of heat lost by the earth, at its present rate of loss, in 23,000,000 years.

Now if this amount of heat, or any sensible fraction of it, was actually generated within a few hundred miles of the earth's surface, the temperature gradient in the earth must be largely due to it, instead of to the primitive heat of the mass.

Such an hypothesis precludes the assumption that the earth is simply a cooling mass, and would greatly prolong the possible extension of geological time. It must be observed that this view is not acceptable unless we admit that the earth can adjust itself to the equilibrium figure adapted to its rotation.

It seems also worthy of suggestion that our data for the average gradient of temperature may be somewhat fallacious. Recent observations (Challenger Expedition) show that the lower stratum of the ocean is occupied by water at near the freezing temperature, while the mean annual temperature of the earth's surface, where the borings have been made, must be at least 30° higher. It does not then seem impossible that the mean temperature gradient for the whole earth should differ sensibly from the mean gradient in the borings already made.

The foregoing remarks have not been made with a view of showing Sir William Thomson's argument from the cooling of the earth to be erroneous, but rather to maintain the scientific justice of assigning limits of uncertainty at the very least as wide as those given by him. Professor Tait (" Recent Advances in Physical Science," 1885) cuts the limit down to 10,000,000 years; he may be right, but the uncertainties of the case are far too great to justify us in accepting such a narrowing of the conclusion.

The third line of argument by which a superior limit is sought for the age of the solar system appears by far the strongest. This argument depends on the amount of radiant energy which can have been given out by the sun.

The amount of work done in the concentration of the sun from a condition of infinite dispersion may be computed with some accuracy, and we have at least a rough idea of the rate of the sun's radiation. From these data Sir William Thomson concludes (Thomson and Tait, " Natural Philosophy," Appendix E):—

" It seems, therefore, on the whole most probable that the sun has not illuminated the earth for 100,000,000 years, and almost certain that he has not done so for 500,000,000 years. As for the future, we may say, with equal certainty, that inhabitants of the earth cannot continue to enjoy the light and heat essential to their life for many million years longer unless sources now unknown to us are prepared in the great storehouse of creation."

This result is based on the value assigned by Pouillet and Herschel to the sun's radiation. Langley has recently made a fresh determination, which exceeds Pouillet's in the proportion of eight to five.* With Langley's value Thomson's estimate of time would have to be reduced by the factor five-eighths.

It has been suggested by Croll that the primitive solar nebula may have been hot. This heat must have arisen from the collision of two or more masses; if their relative velocity before collision was that due simply to their mutual attraction, the heat so generated is already counted in the heat generated by the concentration of the sun from a state of infinite dispersion. But if the relative velocity existed otherwise than from their mutual attraction, then the total heat in the sun might exceed that due simply to concentration. Sir William Thomson considers the hypothesis very improbable. The term improbability seems, however, almost to lose its meaning in these speculations, and at least we know by the spectroscope that actual nebulæ do consist of incandescent gases.

In considering these three arguments I have adduced some reasons against the validity of the first argument, and have endeavored to show that there are elements of uncertainty surrounding the other two; nevertheless they undoubtedly constitute a contribution of the first importance to physical geology. While then we may protest against the precision with which Professor Tait seeks to deduce results from them, we are fully justified in following Sir William Thomson, who says that "the existing state of things on the earth, life on the earth, all geological history showing continuity of life, must be limited within some such period of past time as 100,000,000 years."

If I have carried you with me in this survey of theories bearing on geological time, you will agree that something has been acquired to our knowledge of the past, but that much more remains still to be determined. Although speculations as to the future course of science are usually of little avail, yet it seems as likely that meteorology and geology will pass the word of command to cosmical physics as the converse. At present our knowledge of a definite limit to geological time has so little precision that we should do wrong to summarily reject any theories which appear to demand longer periods of time than now appear allowable.

In each branch of science hypothesis forms the nucleus for the aggregation of observation, and as long as facts are assimilated and coördinated we ought to follow our theory. Thus even if there be some inconsistencies with a neighboring science we may be justified in still holding to a theory, in the hope that further knowledge may enable us to remove the difficulties. There is no criterion as to what degree of inconsistency should compel us to give up a theory, and it should be borne in mind that many views have been utterly condemned, when later knowledge has only shown us that we were in them only seeing the truth from another side. —*Nature*, Sept. 2.

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* Langley (*Ann. Rep. R. A. S.*, 1885) estimates that 3 calories per minute are received by a square centimeter at distance unity. This gives for the total annual radiation of the sun $4{\cdot}38 \times 10^{33}$ calories. Thomson gives as Pouillet's estimate 6×10^{30} times the heat required to raise 1 lb. of water 21° Cels., or $2{\cdot}7 \times 10^{33}$ calories.

2. *On the Genesis of the Elements.* — The address by Mr. Crookes, as President of the Chemical Section of the British Association at the Birmingham meeting, was a noteworthy one. He selected for his subject "the nature and the probable—or at least possible—origin of the so-called elements." After quoting from Faraday, Spencer, Lockyer, Brodie, Stokes and Graham to show that "the notion, not necessarily of the decomposability, but at any rate of the complexity of our supposed elements, is, so to speak, in the air of science waiting to take a further and more definite development," he goes on to discuss the question whether the elements are absolutely and primordially distinct or whether they may not have been evolved from some few antecedent forms of matter—or possibly from only one such—just as it is now held that all the innumerable variations of plants and animals have been developed from fewer and earlier forms of organic life. Conceding that there is no direct evidence of the transmutation of any supposed "element" of our existing list into another, or of its resolution into anything simpler he passes to consider the indirect evidence, that gleaned from the mutual relations of the elementary bodies. Prout's hypothesis, rendered more probable by the half-multiple suggestion of Clarke, shows us that the accepted elements are not coequal but have been formed by a process of expansion or evolution; and since analogy points out that the atomic weight of helium is less than that of hydrogen, this may be the element whose atomic weight will substantiate Prout's law. Another piece of evidence is the close association in the earth's crust of certain groups of elements, such as nickel and cobalt, the two groups of platinum metals, and the so-called rare earths occurring in gadolinite, samarskite, etc., which become more numerous the closer they are examined. The features recognizable in these elements seem to point to their formation severally from some common material placed in conditions in each case nearly identical. So too the doctrine of compound radicals or pseudo-elements, furnishes a weighty argument in favor of the compound nature of the elements, a point to which Carnelley has called attention. If pristine matter was once in an intensely heated condition and has reached its present state by a process of free cooling, the elements as we now have them, as Mills has suggested, may be the result of successive polymerizations. The heat given out in the act of polymerization reverses to some extent the polymerization itself and so causes a partial return to the previous condition of things. This forward and backward movement, several times repeated constitutes "periodicity." Mr. Crookes then discusses the periodic law by the aid of a diagram modified by himself from that of Emerson Reynolds, by inverting it, by representing the pendulous swing as gradually declining in amplitude according to a mathematical law, and by introducing another half swing of the pendulum between cerium and lead, which not only renders the oscillations more symmetrical, but brings gold, mercury, thallium, lead and bismuth on the

side where they are in complete harmony with members of the foregoing groups. "The more I study the arrangement of this zigzag curve," he says, "the more I am convinced that he who grasps the key will be permitted to unlock some of the deepest mysteries of creation. Let us imagine if it is possible to get a glimpse of a few of the secrets here hidden. Let us picture the very beginnings of time, before geological ages, before the earth was thrown off from the central nucleus of molten fluid, before even the sun himself had consolidated from the original *protyle.* Let us still imagine that at this primal stage all was in an ultra-gaseous state at a temperature inconceivably hotter than anything now existing in the visible universe; so high indeed that the chemical atoms could not yet have been formed, being still far above their dissociation-point. In so far as *protyle* is capable of radiating or reflecting, this vast sea of incandescent mist, to an astronomer in a distant star, might have appeared as a nebula showing in the spectroscope a few isolated lines, forecasts of hydrogen, carbon and nitrogen spectra. But in course of time some process akin to cooling, probably internal, reduces the temperature of the cosmic *protyle* to a point at which the first step in granulation takes place; matter, as we know it, comes into existence and atoms are formed. As soon as an atom is formed out of *protyle* it is a store of energy, potential (from its tendency to coalesce with other atoms by gravitation or chemically) and kinetic (from its internal motions). To obtain this energy the neighboring *protyle* must be refrigerated by it and thereby the subsequent formation of other atoms will be accelerated. But with atomic matter, the various forms of energy which require matter to render them evident begin to act; and amongst others, that form of energy which has for one of its factors what we now call atomic weight. Let us assume that the elementary *protyle* contains within itself the potentiality of every possible combining proportion or atomic weight. Let it be granted that the whole of our known elements were not at this epoch simultaneously created. The easiest formed element, the one most nearly allied to the *protyle* in simplicity is first born. Hydrogen—or shall we say helium—of all the known elements the one of simplest structure and lowest atomic weight, is the first to come into being. For some time hydrogen would be the only form of matter (as we now know it) in existence, and between hydrogen and the next formed element there would be a considerable gap in time, during the latter part of which the element next in order of simplicity would be slowly approaching its birth-point; pending this period we may suppose that the evolutionary process which was soon to determine the birth of a new element would also determine its atomic weight, its affinities and its chemical position. In the original genesis, the longer the time occupied in that portion of the cooling down during which the hardening of the *protyle* into atoms took place, the more sharply defined would be the resulting element; and on the other hand with more irregularity in the original cooling, we should have a nearer approach to the state of the elemental family such as we know it at present. In this way, it is conceivable that the succession of events which gave us such groups as platinum, osmium and iridium—palladium, ruthenium and rhodium—iron, nickel and cobalt—if the operation of genesis had been greatly more prolonged would have resulted in the birth of only one element of these groups. It is also probable that by a much more rapid rate of cooling elements would originate even more closely related than are nickel and cobalt and thus we should have formed the nearly allied elements of the cerium, yttrium and similar groups; in fact the minerals of the class of samarskite and gadolinite may be regarded as the cosmical lumber-room where the elements in a state of arrested development—the unconnected missing links of inorganic Darwinism—are finally aggregated." The author then goes on to draw from the assumption already made that the original protyle contained within itself the potentiality of all possible atomic weights, the conclusion that our atomic weights represent merely a mean value around which the actual atomic weights of the atoms vary within certain narrow limits and hence that "each well-defined element represents a platform of stability connected by ladders of unstable bodies. In the first accreting together of the primitive stuff the smallest atoms would form, then these would join together to form larger groups, the gulf across from one stage to another would be gradually bridged over, and the stable element appropriate to that stage would absorb as it were the unstable rungs of the ladder which lead up to it. I conceive, therefore, that when we say the atomic weight of, for instance, calcium, is 40, we merely express the fact that while the majority of calcium atoms have an actual atomic weight of 40, there are not a few which are represented by 39 or 41, a less number by 38 or 42 and so on." If so, then might not these heavier and lighter atoms be sorted out by a process resembling chemical fractionation? In answer to this question, Mr. Crookes gives the results of experiments which he has carried on for several years on the separation by fractional precipitation of the earths of samarskite and gadolinite. "Down to a date comparatively recent," he says, "nothing was more firmly fixed in my mind than the notion that yttria was the oxide of a simple body; and that its phosphorescent spectrum gave a definite system of colored bands. Broadly speaking there is a deep red band, a red band, a very luminous citron-colored band, a pair of greenish-blue bands, and a blue band. . . . . . That the whole system of bands spelled yttria and nothing but yttria, I was firmly convinced. During the later fractionation of the yttria earths and the continued observations of their spectra, certain suspicions which had troubled me for some time assumed consistent form. The bands which hitherto I had thought belonged to yttria began to vary in intensity among themselves and continued fractionation increased the differences first observed. Whilst I was in this state of doubt and uncertainty and only beginning to see my way towards arranging into a consistent whole the facts daily coming to light, help came from an unexpected quarter. M. de Marignac kindly sent me a small specimen of the earth which he had discovered and provisionally named Yα (now gadolinia). In the radiant matter tube this earth gave a spectrum like that of yttria with the chief characteristic band—the citron band—left out, and with the double green band of samaria added to it. A mixture of 61 parts of yttria and 39 parts of samaria gives a spectrum identical almost to the minutest detail with the spectrum of Yα, except that the citron band is as prominent in it as any other line. Yα consists therefore of samaria with the greenish-blue of yttria and some of the other bands of yttria added to it." "I may aptly call the Yα spectrum," he continues, "my Rosetta stone. It threw a flood of light on all the obscurities and contradictions I had found so plentiful and showed me that a much wider law than the one I had been working upon was the true law governing the occurrence of these obscure phenomena. For what does the spectrum of Yα show? It proves that what I had hitherto thought was one of the chief bands in the yttria spectrum—the citron band—could be entirely removed, whilst another characteristic group—the double green of yttria—could also be separated from the citron." The amount of labor involved in these fractionings was very great, a single point often requiring more than 2,000 fractionations to settle it. "Excessive and systematic fractionation has acted the part of a chemical 'sorting demon,' distributing the atoms of yttrium into several groups* with certainly different phosphorescent spectra and presumably different atomic weights, though all these groups behave alike from the usual chemical point of view. Here then is one of the elements, the spectrum of which does not emanate equally from all its atoms but some atoms furnish some, other atoms others, of the lines and bands of the compound spectrum of the element." To test the question whether nature has ever effected such a separation, Mr. Crookes subjected pure yttria (*pure* in respect to every other known element) from different minerals, to the radiant matter test. Samarskite yttria gave all the constituent atom-bands, deep red, red, orange, citron, greenish-blue and blue in fair proportion, the first being faintest. Gadolinite yttrium gave the citron and greenish-blue constituents plentiful, the red very deficient, the orange absent, the others moderate. Xenotime yttria gave the citron the most abundant, the greenish-blue smaller, the red all but absent, and the orange absent. Monazite yttria gave the greenish-blue and the citron, the other constituents being in fair proportion and the red good. Fluocerite yttria is quite similar, though the blue is weaker. Hielmite yttria is very rich in citron, has a fair quantity of blue and greenish-blue, less of red, no orange and only a

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* In a communication to the Section on the fractionation of yttria, Mr. Crookes stated that there are certainly five and probably eight, constituents into which yttrium may be split.

very faint trace of deep red. Euxinite yttria is almost identical with this. Cerite yttria contains most red and citron, less greenish-blue and blue, only a trace of deep red and no orange." "Hence in some, possibly in all elements, the whole spectrum does not emanate from all its atoms, but different spectral rays may come from different atoms, and in the spectrum as we see it all these partial spectra are present together." The address now proceeds further in the order of elemental evolution. In the undulating curve in the diagram may be seen the action of two forces, one acting in the direction of the vertical line and the other pulsating backwards and forwards like a pendulum. The vertical line may be assumed "to represent temperature slowly sinking through an unknown number of degrees from the dissociation point of the first formed element down to the dissociation point of those last shown on the scale. But what form of energy is represented by the oscillating line? Swinging to and fro like a mighty pendulum to points equidistant from a neutral center; the divergence from neutrality conferring atomicity of one, two, three and four degrees as the distance from the center is one, two, three or four divisions; and the approach to or retreat from, the neutral line deciding the electro-negative or electro-positive character of the element—all on the retreating half of the swing being positive and all on the approaching half negative—this oscillating force must be intimately connected with the imponderable matter, essence or source of energy we call electricity. Let us examine this a little more closely. Let us start at the moment when the first element came into existence. Before this time matter as we know it, was not. It is equally impossible to conceive of matter without energy as of energy without matter; from one point of view the two are convertible terms. Before the birth of atoms all those forms of energy which become evident when matter acts upon matter could not have existed—they were locked up in the *protyle* as latent potentialities only. Coincident with the creation of atoms all those attributes and properties which form the means of discriminating one chemical element from another, start into existence fully endowed with energy. The pendulum begins its swing from the electro-positive side; lithium, next to hydrogen in simplicity of atomic weight, is now formed; then glucinum, boron and carbon. Definite quantities of electricity are bestowed on each element at the moment of birth, on these quantities its atomicity depends and the types of monatomic, diatomic, triatomic and tetratomic elements are fixed. The electro-negative part of the swing now commences, nitrogen appears, and notice how curiously position governs the mean dominant atomicity. Nitrogen occupies the position below boron, a triatomic element, therefore nitrogen is triatomic. But nitrogen also follows carbon, a tetratomic body, and occupies the fifth position counting from the place of origin. How beautifully these opposing tendencies are harmonized by the endowment of nitrogen with at least a double atomicity and making its atom capable of acting as tri- and pentatomic. With oxygen (di- and hexatomic) and fluorine (mon- and heptatomic) the same law holds and one half-oscillation of the pendulum is completed. Again passing the neutral line the electro-positive elements, sodium (monatomic), magnesium (diatomic), aluminum (triatomic), and silicon (tetratomic), are successively formed and the first complete oscillation of the pendulum is finished by the birth of the electro-negative elements, phosphorus, sulphur and chlorine; these three—like the corresponding elements formed on the opposite homeward swing—having each at least a double atomicity depending on position. Let us pause at the end of the first complete vibration and examine the result. We have already formed the elements of water, ammonia, carbonic acid, the atmosphere, plant and animal life, phosphorus for the brain, salt for the sea, clay for the solid earth, two alkalies, an alkali-earth, an earth, together with their carbonates, borates, nitrates, fluorides, chlorides, sulphates, phosphates and silicates, sufficient for a world and inhabitants not so very different from what we enjoy at the present day. True the human inhabitants would have to live in a state of more than Arcadian simplicity and the absence of calcic phosphate would be awkward as far as bone is concerned. But what a happy world it would be! No silver or gold coinage, no iron for machinery, no platinum for chemists, no copper wire for telegraphy, no zinc for batteries, no mercury for pumps and alas! no rare earths to be separated." After a discussion of the process as it continues to form the other elements, and the consequences naturally resulting therefrom, the author says: "Summing up all the above considerations, we cannot indeed, venture to assert positively that our so-called elements have been evolved from one primordial matter; but we may contend, I think, that the balance of evidence fairly weighs in favor of this speculation. —*Nature*, xxxiv, 423–432, Sept. 2, 1886.

3. *On Austrium, a new metallic element.*—LINNEMANN has announced the discovery of a new metallic element in the orthite from Arendal to which he has given the name Austrium. To obtain it the mineral is treated with hydrochloric acid, the solution treated with hydrogen sulphide to remove the lead, copper, tin and arsenic, the filtrate nearly neutralized or mixed with sodium-acetate and hydrogen sulphide again passed through it. The precipitate now obtained contained copper, lead, zinc, cadmium, thallium, iron, calcium, magnesium and austrium, these metals being detected by the spark spectra of their chloride solutions. This precipitate was dissolved in hot hydrochloric acid, the excess of acid evaporated, the solution treated with caustic soda in excess, filtered, the filtrate precipitated after warming, with sodium sulphide, the precipitate filtered off and the filtrate allowed to stand exposed to the air. The austrium which it contains is thus converted into carbonate and partly precipitated, mixed with sulphur. On acidifying the filtrate with acetic acid, evaporation to dryness, solution in water and treatment with

hydrogen sulphide, nearly all remaining in solution is thrown down mixed with traces of copper, lead and zinc, separation from the latter being especially difficult. The spark spectrum of the metal austrium is characterized by two violet lines; one of these Aus α has a wave length 4165, the other Aus β has a wave length of 4030. The former appears to coincide with the solar line 4164·7 of Ångström.—*Monatsch. Chem.*, vii, 121; *Ber. Berl. Chem. Ges.*, xix, 431, July, 1886.

4. *On Holmium, Dysprosium and Gadolinium.*—LECOQ DE BOISBAUDRAN has submitted the earth called X by Soret, to a hundred fractionings by means of ammonia and potassium sulphate, and has separated it into two portions. For one of these, whose absorption spectrum exhibits the bands 640·4 and 536·3, he proposes to retain the name holmium; while for the other, containing the bands 753 and 451·5 in its spectrum, he suggests the name Dysprosium (from δυςπρόσιτος, difficultly accessible). Subsequently he gives 804 (?) 756·5, 475, 451·3 and 427·5 as the bands of dysprosium. In a letter to him, Marignac gives the name Gadolinium to the element he has before indicated by Yα. —*C. R.*, cii, 902, 1003, 1005; *Ber. Berl. Chem. Ges.*, xix, 388 (Ref.); *J. Chem. Soc.*, l, 667, August, 1886.

II. GEOLOGY AND NATURAL HISTORY.

1. *Geological Nomenclature: Meeting of the International Committee at Geneva.*—At the meeting of the committee of the International Geological Congress on geological nomenclature, at Geneva, in August last, Messrs. CAPELLINI, the President, DEWALQUE, LAPPARENT, RENEVIER and VILANOVA were present. A proof sheet of the proceedings, yet unfinished, has been received from Mr. Dewalque, the secretary of the committee, and from it the following abstract has been made out.

The question as to the terms Silurian and Cambrian was, by request from England, left for the next general session.

The terms for the higher subdivisions were considered and the following agreed upon, commencing with the highest: (1) *Group*: as, for example, the Primary, Secondary and Tertiary, corresponding to Paleozoic, Mesozoic and Cenozoic.—(2) *Sub-group:* as the Jurassic, Cretaceous.—(3) *System:* as the Liassic.—(4) *Stage* (étage): as the Sinemurian.—(5) *Sub-stage.*

The word *series* was reserved for eruptive rocks, and for use in a general way. For chronological terms, it was decided, on the suggestion of M. Lapparent, that the correlate of Group should be *Era;* of Sub-group, *Time;* of System, *Period;* of Stage, *Age;* of Sub-stage, *Epoch.* By this scheme we should have, for example, the *Mesozoic era, Jurassic time, Liassic period, Sinemurian age*, and under the age, *epochs.* Renevier suggested the use of *sub-era* in place of *time*, but Lapparent's proposition was carried.

A third point considered was the termination of the adjective terms used to indicate subdivisions under the above heads. M. Lapparent thought that it was not best to make any definite proposal at present, on the ground that terms in use were well understood, and the probability of having to modify again. But M. Renevier proposed the following scheme, which was adopted: that the adjective terms of a Group, should have the termination *ary* (*aire* in French) as Primary, etc.; of a System, *ic* (*ique*, Fr.); of a Stage, *ian* (*ien*, Fr.); of a Sub-stage, *ine* (*in*, Fr.).

The following points referred to the committee were answered as follows:

The divisions of highest rank should be based on paleontological characters of universal or world-wide application. The Systems should be marked off by comprehensive facts in paleontology indicative of the general march of progress, especially facts that relate to pelagic species. The common characters of the Systems will necessarily serve for the defining of the Sub-groups. The Stages should be characterized by distinct pelagic faunas; and the Sub-stages should have a regional value. Inferior divisions, having only a local value, were regarded as not coming under the consideration of the International Congress. The committee also decided that a stratigraphic argument needed always to be confirmed by paleontological evidence. J. D. D.

2. *Geological Age of the North Atlantic Oceanic basin and Origin of Eastern American sediments.*—In *Nature*, of Sept. 23, Professor Edward Hull, of Dublin, objects to a statement in President Dawson's Address in which the latter says: "I prefer, with Hall, to consider these belts of sediments as, in the main, the deposits of northern currents, and derived from Arctic land, and that, like the great banks of the American coast of the present day, which are being built up by the present Arctic currents, they had little to do with any direct drainage from the adjacent shore," Professor Hull observing rightly that the deposits spread widely over the continent without reference to the shore line, and that the currents are inadequate in other respects. Mr. Hull states the view he has held, not that the Arctic lands were the source, but the region of the Atlantic, "towards which the sediments thicken, and opposite to that in which the limestones are most developed;" and thence, that the conclusion is inevitable "that the Atlantic was in the main a land-surface in Paleozoic times."

Professor Hull misunderstands American geology in an important respect. The Upper Silurian and Devonian deposits, which have so great thickness to the eastward, stretch northward over central and southern New York, to a large extent behind or west of the Green Mountain region, which was already in shallow water, and probably emerged land; and the Carboniferous formation extends up in the same direction, though to a less distance. Further, the Appalachian Paleozoic beds from their beginning were laid down to a very great extent to the west of the Archæa highlands, those of the chief part of the Blue Ridge, of the Highlands of New Jersey and New York, and of various scattered areas over the higher parts of western New England. If these Archæan lands were largely covered at the close of the Paleozoic era—not a probable supposition for many parts—they were certainly not so during the earlier part, the deposits of which are now below the level of the Archæan lands.

Such facts show that neither the Arctic regions nor any Atlantic continent could have contributed essentially to the growing deposits. Further, the latest results of study among these older deposits satisfy the writer, as it has others, that the origin of the material can be found in the adjoining Archæan of the Eastern Border region; and that the sand reefs and some of the shore lines of the successive periods will be more and more thoroughly traced out over the continent as investigation goes forward: work that was begun and carried well forward when the Professors Rogers, in Pennsylvania and Virginia, and Emmons, Hall, Vanuxem and Mather in New York, made their early investigations nearly fifty years since. J. D. D.

3. *Annual Report of the Geological Survey of Pennsylvania for* 1885; by the State Geologist. 770 pp. 8vo, with 18 plates and many wood-cuts, and an atlas of 8 folded sheets.—The general introduction to this Report by the State Geologist, Professor Lesley, has been noticed on page 162 of this volume. Following this, the volume contains a Preliminary report on Oil and Gas, by JOHN F. CARLL; on the vegetable origin of Coal, by L. LESQUEREUX; on the re-survey of the Pittsburgh Coal-region; by E. V. D'INVILLIERS; on the Coal-beds and fire-clays of the Wellesburg Basin, by J. P. LESLEY, with a special report on fire-clay, by E. B. HARDEN; on the Coal-bed in the Pocono formation, No. X, Second Report of Progress in the Anthracite Coal-region, Part II, on the Brandywine Summit Kaolin beds, and on the Archbald pot-holes, by C. A. ASHBURNER; on the fossils of the Wyoming Valley limestone beds, by A. HEILPRIN; on the Cornwall ore mines, Lebanon Co., by J. P. LESLEY and E. V. D'INVILLIERS; on the origin and distribution of the Delaware and Chester Kaolin deposits, by J. P. LESLEY; General Considerations of the pressure, quantity, composition and fuel value of Rock-gas of Pennsylvania, by J. P. LESLEY; on the buried Wyoming Valley, by F. A. HILL; on a substance resembling dopplerite, by H. C. LEWIS; Progress of the geodetic triangulation of Pennsylvania, by M. MERRIMAN.

The reports in this volume present a general review of many subjects connected with the geology of Pennsylvania, in order to exhibit especially, the great value and extent of the work done, correct popular errors by full explanations, and give general results in connection with the coal, oil, gas, fire-clays, and other products studied by the Survey. Moreover, figures are given of many marine fossils from limestone beds in the coal formation, and a considerable number from the Wyoming anthracite region. It is thus an excellent volume for the State, and a valuable one for the geologist. Its many maps and other illustrations make it easily intelligible and supply much information to the eye. Mr. Ashburner's chapter on the anthracite and other regions show briefly what has been accomplished, and reviews in an instructive way the composition and fuel value of the coal. A very interesting chapter by Lesley and d'Invilliers, gives an account of a bed of magnetite in the Triassic region of Cornwall, in Lebanon County, 300 feet below the surface and nearly 63 acres in estimated area, which became magnetite from limonite by the heat of a trap eruption, and whose original limonite was made through the decay of a ferriferous limestone of the Triassic formation.

The paper by Professor Lesley on rock-gas of western Pennsylvania, its origin, pressure, quantity, composition and fuel-value, supplements the important chapter by Mr. Carll, explaining many points about which there is much popular misunderstanding, and considering from a basis of facts the probable future of gas-production in Pennsylvania, foretelling its rather speedy exhaustion.

Another paper by Professor Lesley, on the Delaware and Chester Kaolin beds, endeavors to explain the origin of these deposits by reference to the known or the probable position of gneiss ridges below the Paleozoic, and the subject leads to remarks on the great amount of denudation in past time over the region, through all periods to the present, and on the origin of kaolin beds generally. As the kaolin beds are beneath or near limestone belts the decay of the limestone, it is suggested, may have helped forward by its liberated carbonic acid and in other ways, the decay of the underlying gneisses. The necessity of favorable conditions for the percolation of waters by opportunities for natural drainage is dwelt upon. The subject is an interesting one and the discussion instructive.

4. *Catalogue of the Blastoidea in the Geological Department of the British Museum*, by ROBERT ETHERIDGE, Jr., of the Department of Geology, British Mus., and HERBERT CARPENTER of Eton College. 322 pp. 4to, with 20 plates. London, 1886.—This "catalogue" contains a very full account of the morphology of the Blastoidea, a discussion of the systematic position of the group, and a revision of the genera and species, with descriptions and illustrations on the plates of their structure and of the species mentioned. The authors are the highest British authority on the subject and understand thoroughly the morphology of Echinoderms. Their work is therefore one of high authority. Mr. Chas. Wachsmuth has been over the same ground, as regards the subject of structure, with like ability, and with the aid of the large diversity of American forms. The authors say in their preface, "our chief difficulty, the want of adequate material, was soon and simply solved; for Mr. Charles Wachsmuth, of Burlington, Iowa, whose admirable work on the Palæocrinoids is known to every palæontologist, generously offered to place at our disposal a selected

series from his fine collection of American Blastoids;" and the collections "lent for six months only," through the owner's liberality remained "for over five years." "Mr. Wachsmuth has also been kind enough to keep us informed of the progress of his own researches, and in some instances these have led to the abandonment or modification of views which we had previously expressed." Messrs. Etheridge and Carpenter differ in some points from Mr. Wachsmuth, "but it is perhaps scarcely to be expected that there should be a complete concordance of opinion between workers who approach the subject from altogether different sides." The authors, besides, express their indebtedness to several other American workers, as also to many in Europe.

The British Museum collection of Blastoids "is not likely to be surpassed in richness," many American species being added to the British, and others from various parts of Europe. All the nineteen genera are represented in it excepting the rare *Pentephyllum* and *Eleutherocrinus.* Of the former, only one specimen (now in the museum of the University of Dublin) is known.

5. *Revision of the Palæocrinoidea,* by CHARLES WACHSMUTH and FRANK SPRINGER. Second Section of Part III. (From the Proc. Acad. Nat. Sci., March, 1886.)—This concluding portion of Part III of Mr. Wachsmuth's important work, covers 194 pages. The subject is the "Discussion of the classification and relations of the Brachiate Crinoids and conclusion of the generic descriptions."

6. *A Natural System of Mineralogy with a Classification of native Silicates;* by THOMAS STERRY HUNT (reprinted from Mineral Physiology and Physiography, pp. 279–401. Boston: S. E. Cassino).—In this essay, which has been already presented to the public in full or in abstract in several publications, Dr. Hunt discusses the general question of mineral classification, and gives the special application to the silicates of the views urged by him.

The subject is too broad to be fully discussed here, but briefly it may be stated that Dr. Hunt urges that in classification not only the chemical composition should be taken into account but the physical characters as well, and especially the specific gravity and hardness. The point made by Dr. Hunt that the hardness and specific gravity, and with them the degree of resistance to attack by solvents, are highly significant as showing the degree of atomic condensation, and hence indicating what species are allied to each other, is one of importance which has been too little recognized.

His method of calculation is applied to the silicates and the results taken in connection with crystallization, hardness and degree of resistance to acids serve to give the basis of the classification. The silicates are thus divided into three sub-orders: (1) those containing no alumina, (2) those with alumina and protoxides, (3) those with alumina and without protoxides. Each of these is separated into five tribes passing from the species of inferior hardness, lower density and easily decomposed by acid to those which are high in hardness and density and not readily decomposed, and then to the softer foliated "phylloid" species, and finally those which are non-crystalline and colloidal. For the details reference must be made to the original paper. In regard to the general result of such a classification it may be said that it for the most part, as was to be expected, serves to bring species together whose relationship has long been recognized, at the same time there are notable exceptions, as when spodumene, which was commonly grouped with the pyroxenes with which it agrees in form, is separated and finds a place beside staurolite. Other cases could be mentioned, but the relations brought out are in any case suggestive and of value.

It is not clear, however, that the chemical basis of the subdivision of the silicates into the three groups mentioned is a necessary consequence of the special principles laid down by Dr. Hunt.

7. *Flowers, Fruits, and Leaves;* by SIR JOHN LUBBOCK, Bart., etc.—In the *Nature Series* of Macmillan & Co., 1886, the articles which were first given as popular lectures and afterwards published in *Nature*, have been collected into this small and very readable volume. That is, to the former Lectures on Flowers—which were published several years ago, at a time where Hermann Muller's writings on the relations of common flowers to Insects were not otherwise very accessible to English and American readers—are now added two equally popular later lectures on fruits and seeds, and on leaves. In all, the structures and forms are especially considered in reference to their utilities, "opening out a very wide and interesting field of study." As the author was not bred to botany and is much given to a particular set of ideas, he now and then runs some risks, but is generally trustworthy as well as interesting in his favorite line of exposition. A. G.

8. *Lectures on the Physiology of Plants;* by SYDNEY HOWARD VINES, M.A., D.Sc., F.R.S., Fellow and Lecturer of Christ's College, Cambridge, and Reader in Botany in the University. Cambridge: University Press, 1886, pp. 710, 8vo.—This handsomely printed and stout volume presents a clear and well arranged and well proportioned summary of vegetable physiology, as it has become under the hands of its productive votaries within the last dozen or so of years. For advanced students this book should accompany and supplement the physiological part of Professor Goodale's Text Book, being naturally fuller in treatment, especially complete in bibliographical references, and entering with much particularity into the discussion of certain rather theoretical questions connected with cell-structure and reproduction. We are thus provided with good abstracts of the present state of our knowledge of the subject, in our own vernacular, and in a presentation which for lucidity and succinctness may not always be found in the German sources or in translations from them. The great advance in vegetable anatomy and physiology of late years naturally is due to the special attention which has been given to them by a numerous class of phytologists, especially on the Euro-

pean continent, who are mainly dissociated from taxonomical botany and morphology. Hence a certain looseness and redundance in terminology, and now and then such confusion as the author of these lectures refers to in his preface,—where we learn that the physiologists speak of the normally lower surface of a leaf as ventral and of the upper as the dorsal, a sort of "*nous avons changé tout cela*" which will astonish the morphologists. A. G.

9. *A Preliminary Synopsis of North American Carices, including those of Mexico, Central America, and Greenland, with the American Bibliography of the Genus;* by L. H. BAILEY, JR., is the modest title of a very elaborate memoir of about 100 pages, just issued as a separate edition of a paper published by the American Academy of Arts and Sciences, in the 22d volume of its Proceedings. It is headed as a "Contribution from the Herbarium of Harvard University," where much of the work was done. It will be prized by our numerous botanists who take a critical interest in the vast genus Carex. The author is one of the professors of the State Agricultural College of Michigan.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *British Association in Birmingham.*—An unusual feature of the British Association this year was the occupancy of the Presidential chair by a member from Canada, Sir J. WM. DAWSON, of Montreal. The inaugural address of the President recognizes in the fact an augury of future international union in scientific work, if not an International Association, remarking that "As a Canadian, as a past President of the American Association and now honored with the Presidency of this Association, I may be held to represent in my own person the scientific union of the British Islands, of the various Colonies and of the great Republic, which, whatever the difficulties attending its formal accomplishment at present, is certain to lead to an actual and real union for scientific work." The address was devoted to various questions in geological science under the general subject of the history (including the permanency or not) of the Atlantic Ocean basin. Other opening addresses were by Professor G. H. DARWIN in the Mathematical and Physical Section; Professor WM. CROOKES, in the Chemical; Professor T. G. BONNEY, in the Geological (relating especially to Britain's Geological history); Professor WM. CARRUTHERS, in the Biological; Sir GEORGE CAMPBELL, in the Anthropological; Sir F. J. GOLDSMID, in the Geographical, and Sir JAMES N. DOUGLASS in the section of Mechanical Science. These able Addresses, together with reports of the work of Committees and Sections, will be found in the numbers of *Nature* for the month of September, commencing with No. 879, or that for September 2d.

OBITUARY.

Colonel CHARLES WHITTLESEY died in Cleveland, Ohio, October 18th, two weeks after entering on his seventy-ninth year. A notice of his geological and other work is deferred.

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DANA'S WORKS.

IVISON, BLAKEMAN, TAYLOR & Co., New York.—**Manual of Geology,** by J. D. DANA. **Third Edition,** 1880. 912 pp. 8vo. $5.00.—**Text-book of Geology,** by the same. **4th ed.** 1883. 412 pp. 12mo. $2.00.—**The Geological Story Briefly Told,** by the same. 264 pp. 12mo. 1875.

J. WILEY & SONS, New York.—**Treatise on Mineralogy,** by J. D. DANA. 5th edit. xlviii and 828 pp. 8vo., 1868. $10.00. The 5th "subedition" was issued by Wiley & Son in April, 1874. (Each "subedition" (or issue from the stereotype plates), contains corrections of all errors discovered in the work up to the date of its publication). Also, Appendix I, by G. J. Brush, 1872. Appendix II, by E. S. Dana, 1875.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 3d edition. 474 pp. 12mo., 1878.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 512 pp. 8vo., 1883.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.—**Manual of Determinative Mineralogy,** with an Introduction on Blow-pipe Analysis, by GEORGE J. BRUSH. 8vo., 2d ed. 1877. Third Appendix to Dana's Mineralogy, by E. S. DANA. 136 pp. 8vo. 1882.

DODD & MEAD, New York.—**Corals and Coral Islands,** by J. D. DANA. 398 pp. 8vo, with 100 Illustrations and several maps. 2d ed., 1874.

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[THIRD SERIES.]

ART. XLVIII.—*On the Crystallization of Native Copper;* by EDWARD S. DANA. With Plates X to XIII.

Literature.

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Historical summary.—The early writers give but little information about the crystallization of native copper. Haüy, and Mohs (1822) figure only the simple crystals showing the combination of the cube, octahedron and dodecahedron. Haüy, however, speaks of a crystal consisting of a low hexagonal pyramid with a short hexagonal prism, which seems to be the same form described by Haidinger in 1824. This latter crystal was from the Nalsö, and showed the tetrahexahedron *e* (210, *i*-2) shortened in the direction of an octahedral axis and probably twinned parallel to the octahedral plane normal to this axis (compare figures 20, 21, Plate XI).

The first important contribution to the subject is that of Rose in 1837. He added to the planes before observed the tetrahexahedron *k* (520, $i\text{-}\frac{5}{2}$) and trisoctahedron *m* (311, 3-3), both on crystals from the Ural. He also gives an interesting description and explanation of the complex crystalline growths afforded by the Siberian mines. He shows that in these forms the branching takes place in the direction of the edges of an octahedral face, that is, at angles of 60°, while the upper and lower parts of the plates are in twinning position to each other. The whole growth consequently forms a single twin, in which the twinning-plane is the octahedral plane in which the branches extend. Rose gives two large figures, projections upon the octahedral twinning-plane which show clearly the ideal relations of the parts of these complex forms.

Lévy about the same time (1837) described twin crystals with *e* alone, and also with *a*, *d*, *o* and *e*; he also mentions the pseudo-hexagonal forms resulting from the distortion and twinning of the tetrahexahedron *e*. Haidinger in 1863 described peculiar hexagonal twins from Burra-Burra in Australia, formed by a combination of the dodecahedron and cube. Schrauf in 1872 gave further obervations of the Australian copper, describing pentagonal dodecahedrons of the form *e*. In 1873 the same writer figured a twin crystal of artificial copper in which *m* (311, 3-3) was prominent. Zerrenner in 1874 mentioned a crystal from Bolivia with *e* and *t* (421, 4-2), but gave no measurements to support the latter form.

Seligmann in 1876 described crystals from the Friedrichssegen mine in Nassau showing pseudohexagonal symmetry, and also twins with orthorhombic symmetry, not unlike forms from Lake Superior explained on a later page. Jérémejew in 1877 described crystals from the Altai with the form *f* (310, *i*-3). G. vom Rath in 1877 gave an interesting account of some Lake Superior crystals with the new hexoctahedron *y* (18·10·5, $\frac{18}{5}\text{-}\frac{9}{5}$); also of a complex combination of this form with the tetrahexahedron *k*, showing a secondary growth of the first form on the second. He gave, too, a brief account of a dendritic crystalline growth analogous to the forms described by Rose.

Fletcher in 1880 added the following new forms: *h* (410, *i*-4), ε (730, $i\text{-}\frac{7}{3}$), δ (740, $i\text{-}\frac{7}{4}$), *l* (530, $i\text{-}\frac{5}{3}$), ω (511, 5-5), μ (411, 4-4), and *v* (531, $5\text{-}\frac{5}{3}$). Of these, Lake Superior specimens yielded all except δ and ω. Lasaulx in 1882 described twin crystals of copper from the Ohligerzug mine near Daaden, on the Sieg. They were polysynthetic octahedral twins, in part with enclosed twinning lamellæ, and in part star-shaped, formed by the grouping of five octahedral crystals about a common center. A form similar to that last mentioned was described in 1883 by Foullon; it was from Schneeberg, in Saxony. The most recent contribution to the subject in hand is that by W. G. Brown in the last number of this Journal. The crystals described by him were artificial and showed some interesting peculiarities of twinning structure.

The list of forms thus identified upon crystals of native copper is as follows:

Cube *a* (100, *i-i*), dodecahedron *d* (110, *i*), octahedron *o* (111, 1); tetrahexahedrons *h* (410, *i*-4), *f* (310, *i*-3), *k* (520, $i\text{-}\frac{5}{2}$), *ε* (730, $i\text{-}\frac{7}{3}$), *e* (210, *i*-2), *δ* (740, $i\text{-}\frac{7}{4}$), *l* (530, $i\text{-}\frac{5}{3}$); trisoctahedrons *ω* (511, 5-5), *μ* (411, 4-4), *m* (311, 3-3); hexoctahedrons *t* (421, 4-2)?, *y* (18·10·5, $\frac{18}{5}\text{-}\frac{9}{5}$), *v* (531, $5\text{-}\frac{5}{3}$).

Through the kindness of Mr. Clarence S. Bement of Philadelphia, the writer has had an opportunity to make a careful study of his beautiful collection of specimens of native copper from Lake Superior, numbering upwards of sixty. A considerable part of these were collected by Mr. Norman Spang, whose exceptional opportunities in this direction, extending over a number of years, were most zealously used; to these Mr. Bement has himself made many important additions. It is not too much to say that these specimens taken together form the finest collection ever made of the crystallized native copper from this remarkable locality, while many of the individual specimens are wholly unique. As will be seen from the descriptions in the following pages the collection offers many points of scientific interest and novelty. In addition to this suite of specimens and a few others from foreign localities, the writer has also had the use of a large number belonging to the cabinets of Professor G. J. Brush and of the Yale College Museum. These have served in some important respects to supplement the Bement collection.

List of planes observed.—The planes which have been observed on the specimens named are: *a*, *d*, *o*; tetrahexahedrons *h*, *k*, *e*, *l*; trisoctahedrons *m*, *n* (211, 2-2); hexoctahedrons *y*, *x* (11·6·1, $11\text{-}\frac{11}{6}$), *z* (12·3·2, 6-4)?. Of these *n*, *x*, *z* are new to the species.

Description of simple forms.—Figures 1 to 12, on Plate X, show the more important of the simple forms in their normal symmetrical development, which have been observed on the Lake Superior specimens. Decidedly the most common type is that of the tetrahexahedrons, and of the four included in the above list *h* and *k* occur most frequently, especially the former. This form *h* (410, *i*-4) is shown alone in fig. 4; it is the most obtuse of the tetrahexahedrons observed on this species and thus approximates most nearly to the cube; its interfacial angles (supplement) are: over $a=28°\ 4'$, over $d=61°\ 56'$, and over the edge $A\ (410 \wedge 401)=19°\ 45'$. Fig. 6 on the other hand gives the tetrahexahedron *l* (530, $i\text{-}\frac{5}{3}$), which approaches nearest to the dodecahedron, it is interesting to note that its angles over *a* and *d* respectively are the same as those of *h* over *d* and *a*. The form *h* is usually combined with the cube (fig. 5) or with the cube, dodecahedron and octahedron (fig. 7); not infrequently *h* and *k* appear together both beveling the cubic edges (fig. 8). In fig. 9 we have the dodecahedron modified by the planes of this same tetrahexahedron. The faces of *h* are commonly striated in a direction normal to the cubic edges owing to an oscillatory combination of the planes of a hexoctahedron which, as noted later, has probably the symbol 12·3·2 (6-4). Not unfrequently, however, the faces of *h* are smooth and free from striations. The form *k* also occasionally shows similar striations.

Of the primary forms of the system, the cube alone is a rather common occurrence, and the dodecahedron occurs though less frequently. The octahedron by itself, however, is not represented at all on the specimens in hand; this may be due in part to accident but seems to show that the octahedral form alone is at any rate much less common than is the case with the other isometric native metals. Fig. 1 gives the nearest approach to the simple octahedron observed, and in fig. 11 the octahedron is shown modified by the hexoctahedron *y*. The octahedron is also prominent in the complex crystalline growth shown in fig. 48.

Fig. 2 represents the only case in which the trisoctahedron *m* (311, 3-3) was observed; this, as will be remembered, is a very common form with gold. Fig. 3 shows a combination, which will be recognized at once as the common garnet form, it is, however, very rare with this species and is only represented by one specimen. The faces of the trisoctahedron are slightly uneven with the tendency to striation common with the species, and hence no exact measurements were possible. The true symbol is obvious, however, since these faces truncate the edges of the dodecahedron; strictly it should perhaps be said that the symbol 211 (2-2) is the one toward which the form closely approximates.

Fig. 10 illustrates a type of crystal represented by several specimens and similar to that described by vom Rath; it is a dodecahedron with the planes of the hexoctahedron *y* (18·10·5, $\frac{18}{5}$-$\frac{9}{5}$). This symbol was assigned by vom Rath with some question, as his measurements were not very precise, but the writer's observations go to confirm his conclusion. The angles of the hexoctahedron are as follows:

Edge *A*.	Edge *B*.	Edge *C*.
18·10·5 $\wedge$ 18·5·10	18·10·5 $\wedge$ 18·10·$\bar{5}$	18·10·5 $\wedge$ 10·18·5
19° 12½′	27° 17⅚′	30° 58′

Also

100 $\wedge$ 18·10·5=31° 50¾′, 110 $\wedge$ 18·10·5=20° 52⅓′, 111 $\wedge$ 18·10·5=36° 44⅓′.

The only one of the above angles which could be measured with really satisfactory precision was the inclination of two opposite faces on the dodecahedral plane; these were found to be 20° 59′ and 21° 0′, which correspond very closely with the calculated angle 20° 52⅓′. Also for 18·10·5 ∧ 18·5·10 was obtained 19° 14′, required 19° 12½′. On two of the specimens the faces of this hexoctahedron were striated coarsely parallel to the edge *C*, owing to the oscillatory combination of this form with a second hexoctahedron approximating closely in position to it. It was not possible to obtain a reliable symbol for the second form.

Another hexoctahedron is shown in fig. 12, which approximates closely to the dodecahedron. Many of the crystals on the specimen giving this combination showed the dodecahedral faces simply divided by faint striations into four fields. Other crystals showed the hexoctahedron distinct, two faces, over the tetrahexahedral edge (*B*), being in oscillatory combination and hence producing a fine striation. In one or two cases the faces were large and smooth enough to yield distinct images with the compound goniometer, and in this way were obtained

$$11\cdot6\cdot1 \wedge 11\cdot1\cdot6 = 33°\ 12' \quad \text{and} \quad 11\cdot6\cdot1 \wedge 11\cdot6\cdot\bar{1} = 9°\ 15'.$$

The various angles for 11·6·1 or $11\text{-}\frac{11}{6}$ are:

Edge *A*.	Edge *B*.	Edge *C*.
11·6·1 ∧ 11·1·6	11·6·1 ∧ 11·6·$\bar{1}$	11·6·1 ∧ 6·11·1
32° 40⅓′	9° 7½′	32° 40⅓′

Also

$$100 \wedge 11\cdot6\cdot1 = 28°\ 56\tfrac{1}{2}', \quad 110 \wedge 11\cdot6\cdot1 = 16°\ 59\tfrac{3}{4}', \quad 111 \wedge 11\cdot6\cdot1 = 34°\ 14'.$$

The agreement is close enough to establish the symbol given as at least representing very closely the position of the form in question. Some of the crystals of this specimen showed the cube also as a prominent form.

Still another hexoctahedron is exhibited by the twin crystal figured on Plate XI (fig. 32). This form is interesting because it is clearly the one whose oscillatory combination produces the fine striation often observed on the faces of the tetrahexahedron *h*. This fact fixes the ratio of two of the axes as 4 : 1 and the measured angle on *a*, the only one obtainable with anything like accuracy serves to establish as the probable symbol 12·3·2 (6-4), which, however, needs confirmation.

100 ∧ 12·3·2 = 16° 43½′ calculated, = 16° 30′ measured. The principal angles for this form are:

Edge *A*.	Edge *B*.	Edge *C*.
12·3·2 ∧ 12·2·3	12·3·2 ∧ 12·3·$\bar{2}$	12·3·2 ∧ 3·12·2
6° 28¼′	18° 22⅙′	60° 18½′.

A number of the specimens showed more or less indistinctly planes of one or more hexoctahedrons, but it was only rarely that it was possible to obtain measurements accurate enough to admit of their determination. The question as to whether they were to be identified with already known forms had usually to be left undecided.

Irregularities of structure of the simple forms.—Native copper is like gold in the frequency with which its crystals show hollow and cavernous forms and other related peculiarities of structure. One specimen consists of a group of simple dodecahedrons, the faces of which show deep irregular cavities. In another the forms are hardly more than skeletons, the crystal, although nearly perfect, being in fact a mere shell. In other cases the edges of the crystal were salient and the faces deeply depressed. One example is given in fig. 15 where the cubic face is depressed, the sides of the depression being taken by the dodecahedral planes. The faces of the cubic planes especially are often thickly covered with quadrilateral pits formed by the dodecahedral planes (fig. 15) or by those of one of the common tetrahexahedrons. Striated faces and faces with wavy irregular surface are also frequently observed. Other irregularities, sometimes of an accidental nature, might be mentioned.

It is also common to observe cases of more or less distinct and regular elevations, triangular or quadrilateral or hexagonal, upon the larger faces. Sometimes these can be referred to known forms, but in others they are too indistinct to be determined. A vicinal tetrahexahedron on the cubic faces is occasionally noted. A prominent example of distinct and regular elevations is given in fig. 13, where at the extremities of the cubic axes there are the projecting pyramids formed by the faces of the tetrahexahedron *l* (530, $i\text{-}\frac{5}{3}$), a form which, as already stated, bears a peculiar relation to *h*.

Figure 13 also illustrates another point in the peculiarities of crystalline structure. One angle of the cube is here cut off by a broad octahedral face, at the center of which the planes of the tetrahexahedron *h* appear forming a small six-sided pyramid. Other crystals show the same thing in greater or less symmetry of development, sometimes several of the octahedral angles being treated in the same way. The octahedral face may be made up of a series of plates with parallel edges, upon which a number of minute pyramids are present, formed in the same way. This peculiarity is interesting because it introduces us to a point immediately to be considered, the tendency of the crystals to develop with rhombohedral symmetry. Thus a number of specimens consist essentially of flattened plates, corresponding to an octahedral plane, whose surfaces are covered with six-sided tabular and pyramidal elevations, the latter often very small and thickly crowded together. These pyramids are always formed by the six planes of a tetrahexahedron, which meet at the extremity of an octahedral axis. When the tetrahexahedron is the form *h*, the angles (supplement) of the scalenohedral pyramid are 61° 56′ and 19° 45′, while the angles at the base of the pyramid are 87° 55′ and 152° 12′ respectively. This is shown in fig. 14. When, however, the elevations are formed by planes of the tetrahexahedron *e* (210, *i*-2), the pyramid is a regular hexagonal pyramid with a pyramidal angle of 36° 52′, and each of the angles at the base is 120°; the latter is more common; it is illustrated in fig. 52.

A secondary growth over an original crystal is sometimes observed. One remarkably symmetrical case of this has been already spoken of as described by vom Rath. Usually the result is to partially obliterate the original form. Thus in one specimen the crystals show numerous tuberose sproutings, suggestive of a fungus growth; in another two large dodecahedral crystals are partially enclosed, each by a rough mass of copper showing only a trace of crystalline form.

Distorted forms and those showing pseudo-symmetry.—Cases showing irregular distortion are common, but among the simple crystals hardly more so than is the case with many other crystallized species. The distortion, on the contrary, usually exhibits a certain degree of regularity, being in the direction of one of the inter-axes of the crystal and thus giving rise to forms with marked pseudo-symmetry. Elongation in the direction of a cubic axis is frequently observed and where symmetrical, produces pseudo-tetragonal forms as shown in fig. 16; compare also figures 48 and 49 described later. Where the elongation is in the direction of one extremity of a cubic axis the forms are hemimorphic in type and more or less irregular.

A symmetrical development of a crystal about an octahedral axis gives rise to forms with rhombohedral pseudo-symmetry and these cases are so frequent and interesting that they are described at length below. Elongated wire- and band-like forms of varied shape, often much curved and twisted, and showing some crystalline markings on the surface, are common but these forms are generally very indistinct, and are hardly to be spoken of as crystals.

Crystals with rhombohedral symmetry.—It is an interesting fact in connection with the crystallization of the native metals, gold, silver and copper, that they so often show a tendency to develop with rhombohedral instead of isometric symmetry. Many cases of this kind have been noted; one striking example has been recently described by the writer,* in which crystals of native gold had essentially the form of an acute rhombohedron ($4R$); these were arranged in parallel position so as to form slender strings of rhombohedrons developed in the direc-

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* This Journal, xxxii, 132, August, 1886.

tion of a trigonal axis of the trisoctahedron (3-3), the other planes of the trisoctahedron forming a pyramid $\frac{4}{3}$-2 and obtuse rhombohedron $\frac{2}{5}R$.

Frequent examples of this tendency have been observed among the specimens of copper under examination, though none so marked as that just mentioned. The following list includes some of the common forms of the isometric system with the symbols that belong to them when placed with an octahedral axis (normal to $11\bar{1}$) vertical, taking the cube with a rhombohedral angle of 90° as the unit form. The vertical axis is then $\overset{|}{c}=1{\cdot}22474$.

	Isometric.			Rhombohedral.	
Cube	a O,	100,	a	$10\bar{1}1$,	R
Octahedron	1,	111,	o	0001,	O
		$11\bar{1}$,	$o_{\prime}$	$02\bar{2}1$,	$-2R$
Dodecahedron	i,	110,	d	$01\bar{1}2$,	$-\frac{1}{2}R$
		$10\bar{1}$,	$d_{\prime}$	$11\bar{2}0$,	i-2
Trisoctahedrons	2-2,	211,	p	$10\bar{1}4$,	$\frac{1}{4}R$
		$11\bar{2}$,	$p_{\prime}$	$10\bar{1}0$,	∞R
		$21\bar{1}$,	$p_{\prime\prime}$	$12\bar{3}2$,	$-\frac{3}{2}$-$\frac{3}{2}$ or $-\frac{1}{2}^{3}$
	3-3,	311,	m	$20\bar{2}5$,	$\frac{2}{5}R$
		$31\bar{1}$,	$m_{\prime}$	$22\bar{4}3$,	$\frac{4}{3}$-2
		$3\bar{1}\bar{1}$,	$m_{\prime\prime}$	$40\bar{4}1$,	$4R$
Tetrahexahedrons	i-2,	210,	e	$11\bar{2}3$,	$\frac{2}{3}$-2
		$20\bar{1}$,	$e_{\prime}$	$21\bar{3}1$,	3-$\frac{3}{2}$ or 1^{3}
	i-$\frac{5}{3}$,	530,	l	$23\bar{5}8$,	$-\frac{5}{8}$-$\frac{5}{3}$ or $-\frac{1}{8}^{5}$
		$50\bar{3}$,	$l_{\prime}$	$53\bar{8}2$,	4-$\frac{8}{5}$ 1^{4}
	i-$\frac{5}{2}$,	520,	k	$32\bar{5}7$,	$\frac{5}{7}$-$\frac{5}{3}$ or $\frac{1}{7}^{5}$
		$50\bar{2}$,	$k_{\prime}$	$52\bar{7}3$,	$\frac{7}{3}$-$\frac{7}{5}$ $1^{\frac{7}{3}}$
	i-4	410,	h	$31\bar{4}5$,	$\frac{4}{5}$-$\frac{4}{3}$ or $\frac{2}{5}^{2}$
		$40\bar{1}$,	$h_{\prime}$	$41\bar{5}3$,	$\frac{5}{3}$-$\frac{5}{4}$ $1^{\frac{5}{3}}$

Among the specimens of native copper two showed rather distinctly the acute rhombohedral form ($-2R$) of fig. 17. The rhombohedral angle is here 70° 32′ and the plane facial angle 60° at the summit. The basal plane which is needed to fill out the eight faces of the normal octahedron was not distinctly present, and in fact the crystals were all lacking in sharpness, though there seems to be no doubt about the interpretation of the form.

Another specimen (fig. 18) showed a long hexagonal prism i-2 ($d_{\prime}$) terminated by an obtuse rhombohedron $-\frac{1}{2}R$ (d), with also subordinate planes of the rhombohedrons $R(a)$, $-2R(o_{\prime})$; in a normal isometric crystal this would be simply a combination of dodecahedron, cube and octahedron. A basal projection (fig. 23) shows the rhombohedral symmetry very clearly. The tetrahexahedron e (210, i-2) is frequently developed according to rhombohedral symmetry, as was early noted by Haüy (see above, p. 413), Haidinger, Lévy and others. As shown in the above list it then corresponds to a hexagonal pyramid of the second or diametral series ($\frac{2}{3}$-2) and a scalenohedron 1^3. The twelve planes of the latter form are often subordinate or nearly absent, and the result is then the pyramid shown in fig. 21; it is this pyramid which, as remarked before, so often covers the surface of broad octahedral plates. In such a form as fig. 21 there is nothing to indicate whether we are dealing with a simple crystal or a twin. If two opposite pairs of these planes are extended the result is an orthorhombic prism terminated by an obtuse pyramid.

Various more or less complex rhombohedral forms occur according as the planes just mentioned are modified by the faces of the cube, dodecahedron or octahedron. Thus in fig. 20 we have the planes of three of these forms together; this represents a simple crystal such as has been repeatedly observed, although twins of similar habit also occur.

One interesting crystal was observed which was a rhombohedral penetration-twin of the tetrahexahedron i-$\frac{5}{3}$ (530) and cube. Of the faces of the first mentioned form the twelve, comprising in the rhombohedral position the negative scalenohedron $-\frac{1}{8}^5$, were prominent, those of the other scalenohedron indistinct; the cubic faces were all present, six above and six below. The twinning plane was the basal (octahedral) plane. The other tetrahexahedrons i-4 and i-$\frac{5}{2}$ are also developed at times, more or less distinctly, after the rhombohedral type, especially the former. The scalenohedron $\frac{2}{5}^2$ forms common six-sided elevations on the octahedral plates, as shown in fig. 14 already alluded to.

Twin crystals.—The specimens of native copper from Lake Superior occur very frequently in twin crystals, although the remark of Rose in regard to the Siberian specimens that simple crystals are rare would not be true of those under examination. The law of twinning is always the same—the twinning-plane a face of the octahedron—but the variety and complexity of these twinned crystals is truly remarkable. The twins are with very rare exceptions contact twins; a few penetration twins have been observed, as also a few cases of repeated twinning.

A penetration-twin of rhombohedral type, with l (530, i-$\frac{5}{3}$) as the predominating form has been spoken of in a preceding paragraph. Another interesting case is shown in fig. 26. The predominating form is the tetrahexahedron k, though the allied form h occurs subordinate, and the octahedron and dodecahedron are both present. From one point of view the crystal appears as a nearly symmetrical cruciform twin, while looking down upon the central octahedral face (as in fig. 26) the habit is rhombohedral. It appears at first sight to be a compound twin but the three octahedral faces in twinning position may all be referred to the same individual; the symmetry of the crystal is nearly equal to that of the drawing.

Figure 22 shows a simple contact twin of the cubo-tetrahexahedron with the usual re-entering angles; this is similar to the forms figured by Lévy. Contact twins of simple habit and normal development are very rare. Octahedral twins of the spinel type have been noted only in a complex growth similar to that represented in fig. 54, and described later.

The spinel law applied to the cube yields the form represented in fig. 25. This is the common type of twins among the Siberian specimens as noted by Rose. Among those from Lake Superior, however, crystals of exactly this form are very rare. Almost invariably, these cubic twins are shortened in the direction of the twinning axis, thus yielding a form consisting of two similar triangular pyramids placed base to base. This form, noted by Sadebeck,* on the native silver from Kongsberg, is represented in fig. 24, and again in fig. 27, the latter in the orthorhombic position as mentioned below. These triangular twin crystals have a most anomalous appearance when they occur alone, suggesting a tetrahedron, or a hemitetragonal trisoctahedron, at first sight. One specimen from the cabinet of Professor Brush shows a broad surface of copper thickly sprinkled with very minute forms (1^{mm} to $\frac{1}{4}^{\text{mm}}$), some of them cubes, others tetrahexahedrons; and not a few are these triangular twins, like fig. 24 or fig. 31, and usually implanted by an acute trihedral angle.

Cases are rare, however, in which these cubic forms appear with this normal development. Generally they are elongated in a direction of a diagonal of the octahedral twinning-face and thus assume the symmetry of a (hemimorphic) orthorhombic crystal. Figure 27 shows this twin in the position corresponding to the latter symmetry. As this method of development is so common it is interesting to note the symbols of the common isometric forms when so placed. Accepting as the fundamental or unit pyramid, two of the cubic faces (100 and 010), the angles of this pyramid are 90° (brachydiagonal edge), and 70° 32′ (front or macro-edge formed by twinning). The plane angle at the summit is 45°. The orthorhombic axes are accordingly:

$$\breve{a} : \bar{b} : \overset{|}{c} = 0{\cdot}8165 : 1 : 1{\cdot}4142$$

The direction of the vertical axis coincides with a diagonal of the octahedral twinning-plane, that of the brachydiagonal

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* Min. petr. Mitth., i, 295, 1883.

axis with the edge of the plane normal to this diagonal, and that of the macrodiagonal axis is the twinning-axis, normal to the twinning-plane.

With respect to these axes the isometric forms met with on these copper twins group themselves as in the following table; the different forms into which the single isometric form separates are indicated, as in the preceding table, by subscript accents.

		Isometric.	Ortho-rhombic.			Isometric.	Ortho-rhombic.
Cube	a	100	111	Octahedron	o	111	014
		010	$\bar{1}11$			$1\bar{1}\bar{1}$	$01\bar{4}$
	a_{I}	$00\bar{1}$	$01\bar{2}$		o_{I}	$\bar{1}11$	$\bar{2}12$
						$\bar{1}\bar{1}1$	212
Dodecahedron	d	110	011			$\bar{1}1\bar{1}$	$\bar{2}1\bar{2}$
	d_{I}	$1\bar{1}0$	100			$\bar{1}\bar{1}\bar{1}$	$21\bar{2}$
	d_{II}	101	103		o_{II}	$1\bar{1}1$	$0\bar{1}0$
		011	$\bar{1}0\bar{3}$			$11\bar{1}$	010
	d_{III}	$10\bar{1}$	$12\bar{1}$				
		$01\bar{1}$	$\bar{1}2\bar{1}$				
	etc.						
Tetrahexahedrons	k	520	377		h	410	355
	k_{I}	$5\bar{2}0$	733		h_{I}	$4\bar{1}0$	533
	k_{II}	502	539		h_{II}	401	436
	k_{III}	$50\bar{2}$	571		h_{III}	$40\bar{1}$	452
	k_{IV}	$20\bar{5}$	$27\bar{8}$		h_{IV}	$10\bar{4}$	$15\bar{7}$
	etc.				etc.		
	e	210	133		e_{II}	201	214
	e_{I}	$2\bar{1}0$	311		e_{III}	$20\bar{1}$	230
					e_{IV}	$10\bar{2}$	$13\bar{3}$

It will be seen from the table that the brachypinacoid (010, *i-ĭ*), is formed by one of the octahedral planes (o_{II} $11\bar{1}$), the macropinacoid (100, *i-ī*) by a dodecahedral plane (d_{I}, $1\bar{1}0$); also one of the planes of the tetrahexahedron *e* is a prism (e_{III} $20\bar{1}=230$, $i\text{-}\breve{\tfrac{3}{2}}$).

All of the planes given in the above list play an important part in these twins. The transformation from the isometric symbol ($h_1h_2h_3$) to that of the corresponding orthorhombic form ($p_1p_2p_3$) is easily accomplished by aid of the equations:

$$p_1=h_1-h_2 \qquad p_2=h_1+h_2-h_3 \qquad p_3=h_1+h_2+2h_3$$

The way in which these twin crystals are developed will be clear from the following descriptions. One specimen of rare beauty and perfection consists of a group of elongated prismatic forms, the longest about $1\frac{1}{2}$ inches in length. In each of them the extremity is formed by a smooth and symmetrically developed pyramid of the form just described, while the elongation in the direction of the diagonal of the twinning-face is somewhat obscure. Figure 33 represents* one of the

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* In the drawing of figures 33, 34, 35, 36, 37, 38, 51, 52, 53, 54, the writer has had the assistance of Mr. J. H. Emerton.

simpler of these forms, as true to nature as possible; figure 35 gives another quite small tapering crystal. In fig. 37 the extremity of a more complex form is represented; here there is a cluster of cubes in parallel position on one side of the form. Other crystals have similar clusters on both sides in their respective twinning positions; they thus serve to reveal the true nature of the terminal pyramid which, taken by itself, might be a serious puzzle, appearing as it does far off from normal isometric forms. The front edge, as seen in fig. 37, is often made up of a series of jagged points formed by a repetition of the lower extremity of the trigonal twin. One of these crystals is so complex a combination of jagged projections on the edges, front and rear and on both lateral edges as to hardly admit of adequate representation.

Another specimen of scarcely less beauty than that just described consists of a group of twin crystals of the same type, but more complex and irregular. In them the common tetrahexahedron *h* (410, *i*-4) is prominent, four planes of this form, those about the cubic face 100, namely 410 (*h*), $4\bar{1}0$ (h_{I}), 401 (h_{II}), $40\bar{1}$ (h_{III}), correspond respectively in the rhombic position to the pyramids 355 ($1\text{-}\breve{\tfrac{5}{3}}$), 533 ($\tfrac{5}{3}\text{-}\tfrac{5}{3}$), 436 ($\tfrac{2}{3}\text{-}\tfrac{4}{3}$) and 452 ($\tfrac{5}{2}\text{-}\breve{\tfrac{5}{4}}$); compare figure 30. Each of these crystals, as is also true of the smaller crystals on the specimen before mentioned, demands a special study before its form can be understood, and this is no easy matter, since exact measurements are out of the question. An adequate illustration of the subject would require an almost indefinite number of ideal as well as artistic figures, since the variety of form is so great.

In fig. 28 the trigonal cubic twin is shown in combination with the octahedron, not an uncommon form, though the crystals of this type are also usually more or less irregularly elongated somewhat as in figures 33, 35 and 37. Figure 31 shows a similar trigonal twin combined with the cube and part of the planes of the tetrahexahedron *h*; this in the orthorhombic projection appears as in fig. 29. Fig. 30 is another more complex trigonal twin similar to fig. 31, and fig. 32 exhibits the same habit, but instead of the tetrahexahedron we have the hexoctahedron *x* already described.

Crystals of the type represented in figs. 29 and 30, when developed after the orthorhombic type, form acute, flattened spear-head crystals, as shown in the drawings (figures 36 and 38). In these cases the crystals are flattened in a direction *normal to* the twinning-plane, but in other cases the flattening is parallel to it, as described in the next paragraph. Very frequently on one or both sides some trace of the cube is shown by which the form can be orientated, and not infrequently the tetrahexahedral planes can be seen on the cubic faces in their normal development. The front edge is sometimes sharp and jagged in the way described, by the repetition of the lower angle of the trigonal twin. Figure 34 shows this point well; it is drawn (like the simple figure 40) with the twinning-plane parallel to the plane of the paper instead of normal to it, as in all the figures previously spoken of. These simpler specimens often show traces of the complex growth along lines at angles of 60°, and thus pass into such forms as that represented in fig. 51. Other specimens show other forms of the same type, but differing most widely according to the planes present and according to their relative development. In almost all of these the tendency to develop in orthorhombic symmetry is strongly marked.

The tetrahexahedron *e* is an interesting case, since it gives a prismatic form, 230 (i-$\breve{\frac{3}{2}}$), terminated above and below by a brachy-pyramid 133 (1-$\breve{3}$). This form, which is not an uncommon one, and appears as a spear-head crystal flattened *parallel* to the twinning-plane, is especially noteworthy because it is in this position a normal orthorhombic form, not hemimorphic like the others. The same form may come without twinning from the shortening of the tetrahexahedron in the direction of an octahedral axis and a simultaneous elongation parallel to the middle pair of planes (compare fig. 21 and p. 421).

Another type of twin crystal, somewhat related to those just described, but of very different aspect, is shown in fig. 44. The first crystal studied proved to be a problem of some difficulty, especially as it was very small and only a few planes gave distinct reflections. At first sight it appeared to be a square prism terminated somewhat acutely by an octagonal pyramid and with several small modifying planes. The measurement of a few angles served to unravel the form. The pyramidal angles of two corresponding pairs of planes, measured with fair precision, were found to be

38° 55′ and 39° 7′;

the angles of the other approximately measured gave

30° to 31°.

The first angles given correspond to the angle between two adjacent planes of a twinned octahedron:

$$o \wedge \underline{o} = 38° \, 56'.$$

The other pyramidal angle corresponds to that (30° 27′) between two planes of the tetrahexahedron *k* (520, i-$\frac{5}{2}$). Other angles, measured with more or less accuracy, served to show that the planes present included the cube (*a*), octahedron (*o*), dodecahedron (*d*) and tetrahexahedron *k* (520, i-$\frac{5}{2}$). Figure 44 shows it in ordinary projection, and in fig. 43 a basal projection is given; the rather close approximation to a tetragonal crystal is obvious at a glance ($o_{II}\ d_{I} = 90°$).

The same specimen showed other crystals perplexingly like those just described, especially in that they were terminated by a pair of planes looking very similar to the pair of cubic planes in fig. 44. The measured angle between them was, however, about 39° (38° 56′) instead of 70° 32′ (the angle between two cubic faces in twinning position), and they were thus seen to be octahedral faces in twinning position to each other. These forms proved to be the complementary half of the crystal just described, as is shown in fig. 45, which is a projection upon the twinning plane; here both parts, not in fact observed together on the same crystal, are represented together. In fig. 45 the octahedral edge is placed above, to correspond with the symbols given on p. 423. The forms shown in figs. 43–45 are spoken of further in a later paragraph, where the method of grouping (see figs. 46 and 54) is described. The understanding of this type of twin will be facilitated by reference to the simple forms in figs. 39 to 42, all drawn with the twinning-plane parallel to the plane of the paper. Figure 39 is a simple octahedral twin of the spinel type; fig. 40 the trigonal cubic twin already fully described. In fig. 41 the octahedral twin is shown, but much flattened and with the cubic faces on the angles; this is also a copper form. Finally, fig. 42 is the cubic twin with the octahedral faces.

Still another type of twin is represented in fig. 47, which, like those already described, very rarely shows a re-entrant angle. The figure is a projection upon the twinning-plane. The crystals of this type are elongated prisms, one edge formed by two octahedral planes ($o_{,} \wedge \underline{o}_{,} = 38° 56'$) and the other by the pseudo-planes ϑ ($\vartheta \wedge \underline{\vartheta} = 90° 54'$). The figure is placed so as to show the prismatic development, but to understand it, it must be turned so that the plane o_{I} is parallel to the same plane in fig. 45; then h and h_{III} correspond to the tetrahexahedron k and k_{III} present there, etc. The pseudo-planes ϑ and ϑ' are formed by the oscillatory combination of two adjacent tetrahexahedral planes h and h_{III}, etc., and are in fact only a series of fine ridges. Were they real planes the symbol for ϑ would be $81\bar{1}$ (8·8) in the isometric system, or 7·10·7 in the orthorhombic position. Twins of this type are sometimes very regular and symmetrical and again highly irregular, and varying much from the simple prismatic form.

Methods of grouping.—The specimens of native copper very commonly show, instead of an irregular combination of crystals, a grouping in parallel position with sharply defined lines of growth. Two methods of grouping are most common. In the first the lines of growth (the "tectonic axes" of Sadebeck) of the adjoining crystals or parts of crystals (sub-individuals) are the cubic axes; in the second they are axes inclined 60° to each other and generally coinciding with the diagonals of an octahedral face, that is, the lines normal to its edges and bisecting the facial angles. A third method, quite different from the others, has also been observed.

The first method is common with many isometric species, and is represented here in several different forms. Thus one specimen is made up of small cubes grouped in this way. In another there are several series of octahedrons each having a common vertical axis, and each octahedron made up of many small partial octahedrons (like fig. 1), the whole specimen a wonderfully delicate and beautiful arborescent growth. Figs. 48 and 49 show interesting cases of the same thing. In fig. 48 the predominating forms are the octahedron and dodecahedron, though the terminal crystals are sometimes as complex as fig. 16. On this specimen we have sometimes a long wire with projecting points of small octahedrons; then more complex growths with branchings and rebranchings, and again a close even network of rectangular ribs. In fig. 49 the form involved is the tetrahexahedron *h* (410, *i*-4) and the lines of growth are uniformly the cubic axes; as will be inferred from the figure the specimen is one of much beauty and interest.

The second method of grouping is, however, the more interesting, especially so in that the crystals taking part in it are generally twins. Here the twinning-plane is the plane in which the lines of growth lie and these axes are three lines crossing at 60° and situated as described. The explanation of an analogous method of grouping was given by Rose in his description of the complex growth among the Siberian crystals already spoken of. The Lake Superior specimens differ from the Siberian in that, although the branching is also at 60°, the directions are almost always those of the *diagonals* of the octahedral face, not of the *edges.* This statement is true of all the Lake Superior specimens the writer has had the opportunity to examine with a single exception, while one beautiful specimen from Siberia in Mr. Bement's collection agrees with the description of Rose. It may be noted here that Sadebeck describes both these systems of "tectonic axes" as occurring in the dendritic growths of native silver, and he also mentions having observed the diagonal method of growth himself in copper. The Lake Superior specimen described by vom Rath is stated to have conformed to the method given by Rose.

An ideal representation showing the common method of growth spoken of, of the trigonal cubic twins, is given in fig. 50. The actual forms are, however, most complex, for instead of simple cubes we may have either one of the commoner tetrahexahedrons or a combination of one or more of them with each other or with the cube, octahedron and dodecahedron. Moreover, we have sometimes an open series of cubic twins, and from these we pass to more compact forms and finally to specimens which are simple plates with broad octahedral surface showing the characteristic spear-shaped twins only occasionally at the edges and with the hexagonal lines of growth only slightly accentuated. In the latter cases the octahedral surface is commonly covered over, often very thickly, with hexagonal elevations formed by one of the common tetrahexahedrons as already described. Still further, a number of these branching dendritic growths may be grouped in slightly diverging position about a common center, thus producing arborescent crystallizations of great beauty.

The twinning is also often somewhat complex; for it may be not simply a case of a single twin growth with the upper surface in twinning position with respect to the lower, but on the same side any one of the tectonic axes may be taken by a series of cubic twins in reversed position to those adjoining, or a single crystal in twinning position may appear in the midst of the others.

Fig. 51 represents ($\frac{4}{5}$ths natural size) one of the finest of these remarkable specimens. It illustrates admirably the method of growth and the remarkable complexity of the resulting forms. The spear-head forms at the extremities are here well seen. It is to be noted also, in illustration of a point just made, that for the lower part of the specimen the crystals are in twinning position with reference to the majority of the others, and this is true also of isolated cubes at various other points as at *a*, *a*. Fig. 52 shows one of the tabular forms in which the octahedral plane predominates, and it is only on the central and branching ribs that the other—tetrahexahedral—forms are distinct. The surface is thickly covered with hexagonal plates and low pyramids, which the drawing only in part represents.

In fig. 53 a partially satisfactory representation is given of a very delicate moss-like dendritic crystallization which is especially interesting because careful examination proves that the tectonic axes here are situated diagonally with reference to the common method, in other words it is like the forms figured by Rose. The specimens are nearly an inch in length and very thin and fragile. The octahedral surface is prominent, though cubes in thin plates, or in normal forms, project from it sometimes in one position, sometimes reversed—over one surface there are a number of tetrahexahedrons with rhombohedral (scalenohedral) development implanted on the octahedral surface; these are also in both positions.

A novel and interesting method of grouping, different from those described, is represented by several fine specimens. The crystal individuals taking part in it have already been partially described (see figs. 43, 44, 45). The larger specimen, as shown in the drawing, fig. 54, consists essentially of a long slightly curved line, deeply grooved along the center, from which project above and below, in two directions crossing at angles of 70° 32′ and 109° 28′, a series of small (2^{mm}) partial crystals. This line of elongation is one edge of the twinning octahedral plane. The crystals above and below form the two parts of fig. 45. Those below terminating in the cubic twinning-edge have a rather constant habit as shown in fig. 46. The crystals above, however, which terminate in an octahedral twinning-edge, vary much, and have a marked tendency to develop in forms similar to those below by elongation to one side in a direction normal to the cubic edge. This is suggested by the forms in fig. 46; but other crystals are very much more elongated and incline to one side at a sharp angle. Others of these crystals are broad plates showing but few planes except at the edges.

The smaller specimens of this type show also more distinctly a second similar line about the same axis and crossing the others at the octahedral angle of 70° 32′. Fig. 55 gives a cross-section in outline, and makes clear what the relations of the two series are. The individuals I and II are in twinning position with the octahedral edge above. The individuals III and IV are also in twinning position with the adjacent octahedral plane as twinning-plane, and in such a manner that the first twinning-plane is parallel to the octahedral face of III which forms the edge of III and IV. Another specimen showed the same method of complex growth, though the component crystals were simpler, some of them being simple spinal twins like fig. 39. The lines in all these cases when naturally terminated, taper off to a rather fine point.

In concluding this paper, upon a subject which cannot by any means be regarded as exhausted, the writer would express his thanks to Mr. Clarence S. Bement for his kindness in allowing him the free use of his valuable collection for several months, and also for the substantial support which has made so liberal a degree of illustration possible.

ART. XLIX.—*On the Trap and Sandstone in the Gorge of the Farmington River at Tariffville, Conn.;* by WILLIAM NORTH RICE.

THE trap of the Connecticut Valley, as is generally known, occurs for the most part in sheets intercalated among the sandstones and associated rocks, and apparently perfectly conformable with the sedimentary rocks in their generally easterly dip. Diverse views have been maintained in regard to the history of these sheets of trap, some writers considering them contemporaneous, others considering them intrusive, and still others holding that some of the sheets are contemporaneous and others are intrusive. The last view is set forth by Prof. W. M. Davis, in his paper "On the Relations of the Triassic Traps and Sandstones of the Eastern United States,"* a paper which, in addition to most important original observations bearing upon the question, gives a very complete résumé of the literature of the subject. If it be true, as I believe it is, that some of the sheets are contemporaneous and others intrusive, there is obviously need of special study to make out the history of each one. My purpose in the present note is to offer a contribution to this study by calling attention to one remarkably instructive locality.

The long range of trap hills which extends almost continuously from the Hanging Hills of Meriden to Mt. Holyoke, includes (at least for the greater part of its course in Connecticut) two sheets of trap, which are generally strongly contrasted with each other.† The lower, or western, sheet is generally highly amygdaloidal, containing chlorite, calcite, datolite, prehnite, and occasionally copper ores; and does not usually show any very distinct columnar structure. The upper, or eastern, sheet is generally not amygdaloidal, and is generally much more distinctly columnar than the former. The main crest of the range is formed by the upper, or eastern, sheet of trap. The lower, or western, sheet forms sometimes a lower parallel ridge ("anterior range" of Percival). In other places the lower sheet forms merely a terrace on the western face of the main ridge. This terrace is very well marked on Talcott mountain, a portion of the range lying west of Hartford, and much visited on account of its magnificent prospect.

At the village of Tariffville, in the northeast corner of the town of Simsbury, the Farmington river cuts through the

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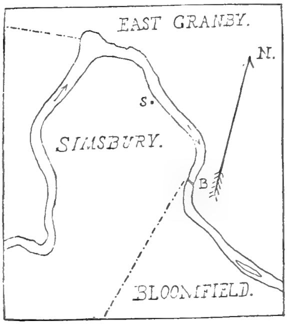
* Bulletin of the Museum of Comparative Zoology, vol. vii (Geological Series, vol. i), no. ix.

† Percival, Geology of Connecticut, pp. 369, 390.

range of trap hills, forming a most picturesque gorge, and beautifully exposing the geological structure. The accompanying map (on a scale of $\frac{5}{6}$ths of an inch to the mile) shows the position of the localities referred to. The letter S indicates the location of the Tariffville station of the Hartford and Connecticut Western R. R. At the point marked B, where the boundary between the towns of Simsbury and Bloomfield meets the river, the river is crossed by a bridge. Southward the boundary between Simsbury and Bloomfield runs along the crest of the trap range. On the left bank of the river, for some distance above the bridge, rises a bold line of cliff about two hundred and fifty feet in height, formed by the upper sheet of trap, which here presents its usual characters, being highly columnar and not amygdaloidal. Above the bridge, the sandstone appears at the base of the cliff, forming for a considerable distance the immediate bank of the river; but, in the slight westerly bend in the immediate vicinity of the bridge, the river has cut down through the sandstone into the underlying amygdaloid. Starting accordingly, from the bridge on the left bank of the river, it is easy to examine the whole thickness of the strata from the top of the lower (amygdaloidal) trap to the base of the upper (columnar) trap. The thickness of the strata is apparently about twenty feet, though it would require a little surveying to determine the thickness with any degree of accuracy, as coverings of talus and vegetation and the water of the river prevent the whole thickness from being accessible at any one point. The rocks are more conveniently studied above the bridge than below it, being less covered by vegetation.



Starting from the margin of the stream at the bridge, and proceeding upward until we reach the upper sheet of trap, we may observe the following succession in the phenomena presented by the rocks:

1. The greenish gray amygdaloid which forms the main part of the lower sheet of trap.

2. The same becoming less lustrous, less greenish in color, and having the amygdules more copiously distributed, as we approach its upper surface.

3. A conglomerate, containing pebbles of amygdaloid. Many of the pebbles show the rounded form of water-worn pebbles. Some of them show superficial alteration, such as is common in pebbles of trap exposed to the action of air and water. The matrix in which the trap pebbles are imbedded, is the or-

dinary material of the brownish red sandstones, showing no sign of induration or alteration.

4. A red, shaly sandstone, perfectly normal and unaltered.

5. Sandstone, brighter red in color, somewhat indurated (but no more so than is frequently the case in places remote from igneous action), so fine grained as to approach in that respect the character of a shale, but not laminated, appearing vesicular where it has been weathered, but having the cavities below the surface filled with calcite.

6. Fine-grained purplish gray or dove-colored sandstone.

7. A highly metamorphosed sandstone, greenish gray in color, and so highly crystalline that hand specimens of it would be mistaken for trap. This extreme condition of metamorphism extends downward two or three feet from the junction with the overlying trap. Calcite in minute particles is disseminated through the mass of this metamorphosed rock.

8. Just at the junction of the sandstone with the overlying trap, a seam about three inches in thickness, decomposed and crumbling, appearing when wet about like a layer of mud.

9. The overlying trap, for a short distance above the junction, black and almost lusterless.

10. The black, lustrous, highly crystalline trap of the upper sheet, in its normal character.

These phenomena seem to lead irresistibly to the conclusion that the lower sheet of trap is contemporaneous. The increasingly amygdaloidal character of the trap near its upper surface, the weathered and water-worn pebbles of trap in the lowest layer of the stratified rocks, the perfectly unaltered character of the lower layers of sandstone, so strongly contrasted with the intense metamorphism of the layers near the contact with the overlying trap—all find their explanation in this view.

If the lower sheet of trap is contemporaneous, it would be a natural conjecture that the upper one is also contemporaneous. On this point, however, I have no positive evidence. I followed the bank of the river down stream till I reached the outcrop of the overlying sandstone, but found no contact visible. The only fact noted which has any significance in relation to the question, is that the trap of the upper sheet changes its character near its upper surface, becoming greenish gray in color and minutely amygdaloidal. Amygdules of calcite about the size of the head of a pin are somewhat abundant. This fact, so far as it goes, is in favor of the conjecture above stated.

The railroad to Hartford runs along the right bank of the river; and, in following the curves of the river, it passes through two cuttings in the lower or amygdaloidal sheet of trap. In the more northerly of the two cuttings is to be seen a peculiar breccia, forming a nearly vertical band two or three feet in width, appearing almost like a vein or dike intersecting the trap. In this breccia the trap and sandstone are confusedly mixed together. The appearance is suggestive of a friction breccia;[*] but, on closer examination, the structure is seen to be quite different from von Cotta's description of a friction breccia. Here the matrix seems to consist of the material of the red sandstone, while the included pebbles are of trap. The trap fragments, especially the smaller ones, are extensively altered to chlorite. In the immediate vicinity of this breccia, the trap shows joints with slickensides. It would seem as if the formation of this breccia was due to some disturbance subsequent to the outflow and consolidation of the trap. The breccia may probably be considered to be a "fault-rock."[†] The occurrence of disturbances subsequent to the consolidation of the trap is confirmed by an examination of the more southerly cutting, where two unmistakable faults may be seen. In the southern cutting the contact of the amygdaloid with the overlying sandstone is exposed; but the rocks at that point are too much decomposed to afford any satisfactory observations. There seems to be nothing in the phenomena observed in the cuttings on the right bank of the river, which contradicts the evidence of the contemporaneous origin of the trap afforded by the section on the left bank.

Wesleyan University, Middletown, Conn, Aug. 13, 1886.

ART. L.—*Comparative Studies upon the Glaciation of North America, Great Britain, and Ireland;* by Professor H. CARVILL LEWIS. (Abstract by the author of a paper read at the Birmingham meeting of the British Association, September, 1886.)

THE object of this paper was to show that the glacial deposits of Great Britain and Ireland, like those of America, may be interpreted most satisfactorily by considering them with reference to a series of great *terminal moraines*, which both define confluent lobes of ice, and often mark the line separating the glaciated from the non-glaciated areas.

The paper began with a sketch of recent investigations upon the glaciation of North America, with special reference to the significance of the terminal moraines discovered within the last few years. The principal characters of these moraines were given, and a map was exhibited showing the extent of the glaciated area of North America, the course of the interlobate and

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[*] Von Cotta, Rocks Classified and Described, p. 305.

[†] Geikie, Text-book of Geology, 2d edition, p. 161.

terminal moraines and the direction of striation and glacial movement. It was shown that, apart from the great ice sheet of Northeastern America, an immense lobe of ice descended from Alaska to Vancouver's Island on the western side of the Rocky Mountains and that from various separate centers in the Cascade, Sierra Nevada, and Rocky Mountains there radiated smaller local glaciers.

The mountains encircling the depression of Hudson Bay seemed to be the principal source of the glaciers which became confluent to form the great ice sheet. In its advance this ice sheet probably met and amalgamated with a number of already existing local glacial systems, and it was suggested that there was no necessity for assuming either an extraordinary thickness of ice at the Pole, or great and unequal elevations and depressions of land.

Detailed studies made by the author in Ireland, in 1885, had shown remarkably similar glacial phenomena. The large ice sheet which covered the greater part of Ireland was composed of confluent glaciers, while distinct and local glacial systems occurred in the non-glaciated area. The principal ice sheet resembled that of America in having for its center a great inland depression surrounded by a rim of mountains. These appear to have given rise to the first glaciers, which after uniting, poured outward in all directions. Great lobes of this ice sheet flowed westward out of the Shannon, and out of Galway, Clew, Sligo, and Donegal Bays, northward out of Loughs Swilly and Foyle, and southeasward out of Dundalk and Dublin Bays; while to the south the ice sheet abutted against the Mullaghareirk, Galty, and Wicklow mountains, or died out in the plains. Whether it stopped among the mountains or in the lowlands, its edge was approximately outlined by usual accumulations of drift and bowlders, representing the terminal moraines. As in America, this outer moraine was least distinct in the lowlands, and was often bordered by an outer "fringe" of drift several miles in width.

South of an east and west line extending from Tralee to Dungarven is a non-glaciated zone free from drift. Several local systems of glaciers occur in the south of Ireland, of which by far the most important is that radiating from the Killarney mountains, covering an area of over 2000 square miles, and entitled to be called a local ice sheet. Great glaciers from this Killarney ice sheet flowed out of the fiord-like parallel bays which indent the southwestern coast of Ireland. At the same time the Dingle mountains, the Knockmeal Down and Comeragh mountains, and those of Wexford and Wicklow furnished small separate glaciers, each sharply defined by its own moraine.

No evidence of any great marine submergence was discovered, although the author had explored the greater part of Ireland, and the eskers were held to be phenomena due to the melting of the ice and the circulation of subglacial waters. The Irish ice sheet seemed to have been joined at its northwestern corner by ice coming from Scotland across the North Channel. All the evidence collected indicates that a mass of Scotch ice, reinforced by that of Ireland and England, filled the Irish Sea, overriding the Isle of Man and Anglesey, and extending at least as far south as Bray Head, south of Dublin. A map of the glaciation of Ireland was exhibited in which the observations of the Irish geologists and of the author were combined, and in which were shown the central sheet, the five local glacial systems, all the known striæ, and the probable lines of movement as indicated by moraines, striæ and the transport of erratics.

The glaciation of Wales was then considered. Wales was shown to have supported three distinct and disconnected local systems of glaciers, while at the same time its extreme northern border was touched by the great ice sheet of the Irish Sea. The most extensive local glaciers were those radiating from the Snowdon and Arenig region, while another set of glaciers radiated from the Plinlimmon district and the mountains of Cardiganshire, and a third system originated among the Brenockshire Beacons. The glaciers from each of these centers transported purely local bowlders and formed well-defined terminal moraines. The northern ice lobe, bearing granite bowlders from Scotland and shells and flints from the bed of the Irish Sea, invaded the northern coast, but did not mingle with the Welsh glaciers. It smothered Anglesey and part of Carnarvonshire on one side, and part of Flintshire on the other, and heaped up a terminal moraine on the outer flanks of the north Welsh mountians. This great moraine, filled with far-traveled northern erratics, is heaped up in hummocks and irregular ridges and is in many places as characteristically developed as anywhere in America. It has none of the characters of a sea-beach, although often containing broken shells brought from the Irish Sea. It may be followed from the extreme end of the Lleyn Peninsula (where it is full of Scotch granite erratics), in a northeasterly direction through Carnarvonshire past Moel Tryfan and along the foot of the mountains east of Menai Strait to Bangor, where it goes out to sea, re-appearing farther east at Conway and Colwyn. It turns southeastward in Denbighshire, going past St. Asaph and Halkin Mountain. In Flintshire it turns southward and is magnificently developed on the eastern side of the mountains, at an elevation of over 1000 feet between Minera and Llangollen, southwest of which place it enters England. There is evidence that where the ice sheet abutted against Wales, it was about 1350 feet in thickness. This is analogous to the thickness of the ice sheet in Pennsylvania, where the author had previously shown that it was about 1000 feet thick at its extreme edge and 2000 feet thick at points some eight miles back from its edge. The transport of erratics coincides with the direction of striæ in Wales as elsewhere, and is at right angles to a terminal moraine.

The complicated phenomena of the glaciation of England, the subject of a voluminous literature and discordant views, had been of high interest to the author, and had led him to redouble his efforts toward its solution. He had found that it was possible to accurately map the glaciated areas, to separate the deposits made by land ice from those due to icebergs or to torrential rivers, and to trace out a series of terminal moraines both at the edge of the ice sheet, and at the edge of its confluent lobes. Perhaps the finest exhibition of a terminal moraine in England is in the vicinity of Ellesmere and Shropshire. A great mass of drift several miles in width, and full of erratics from Scotland and from Wales, is here heaped up into conical hills which enclose "kettle-holes" and lakes, and have all the characters of the "kettle moraines" of Wisconsin. Like the latter, the Ellesmere moraine here divides two great lobes of ice, one coming from Scotland, the other from Wales. This moraine may be traced continuously from Ellesmere eastward through Madeley, Macclesfield, to and along the western flank of the Pennine chain, marking throughout the southern edge of the ice sheet of northern England. From Macclesfield the same moraine was traced northward past Stockport and Staley Bridge to Burnley, and thence to Skipton in Yorkshire. Northeast of Burnley it is banked against the Boulsworth Hills up to a height of 1300 feet, in the form of mounds and hummocks. South and east of this long moraine no signs of glaciation were discovered, while north and west of it there is every evidence of a continuous ice-sheet covering land and sea alike. The striæ and the transport of bowlders agree in proving a southerly and southeasterly direction of ice movement in Lancashire and Cheshire.

From Skipton northward the phenomena are more complicated. A tongue of ice surmounted the watershed near Skipton and protruded down the valley of the Aire as far as Bingley, where its terminal moraine is thrown across the valley like a great dam, reminding one of similar moraine dams in several Pennsylvania valleys. A continuous moraine was traced around Aire glacier. Another great glacier, much larger than this, descended Wensleydale and reached the plain of York. The most complex glacial movements in England occurred in the mountain region about the Nine Standards, where local glaciers met and were overpowered by the greater ice sheet coming down from Cumberland. The ice sheet itself was here divided, one portion going southward, the other in company with local glaciers and laden with the well known bowlders of "Shap granite" being forced eastward across Stainmoor Forest into Durham and Yorkshire, finally reaching the North Sea at the mouth of the Tees. The terminal moraine runs eastward through Kirkby Ravensworth toward Whitby, keeping north of the Cleveland Hills, and all eastern England south of Whitby seems to be non-glaciated. On the other hand all England north of Stainmore Forest and the river Tees, except the very highest point, was under a sea of solid ice.

There is abundant evidence to prove that the ice lobe filling the Irish Sea was thicker toward its axis than at its edges, and at the north than at its southern terminus, and that it was reinforced by smaller tributary ice streams from both England and Ireland. It may be compared with the glacier of the Hudson river valley in New York, each having a maximum thickness of more than 3000 feet. The erosive power of the ice sheet was found to be extremely slight at its edge, but more powerful farther north, where its action was continued for a longer period. Toward its edges its function was to fill up inequalities rather than to level them down. It was held that most glacial lakes are due to an irregular dumping of drift, rather than to any scooping action, observations in England and in Switzerland coinciding with those in America to confirm this conclusion. Numerous facts on both sides of the Atlantic indicate that the upper portion of the ice sheet may move in a different direction from its lower portion. It was also shown that a glacier in its advance had the power of raising stones from the bottom to the top of the ice, a fact due to the retardation by friction of its lower layers. The author had observed the gradual upward passage of sand and stones in the Grindelwald glacier, and applied the same explanation to the broken shells and flint raised from the bed of the Irish Sea to the top of Moel Tryfan, to Macclesfield and the Dublin mountains. The occurrence of stratified deposits connected with undoubted moraines was shown to be a common phenomenon, and instances of stratified moraines in Switzerland, Italy, America and Wales were given. The stratification is due to waters derived from the melting ice, and is not proof of submergence.

It was held, notwithstanding a general opinion to the contrary, that there is no evidence in Great Britain of any marine submergence greater than about 450 feet. It was to be expected that an ice sheet advancing across a sea should deposit shell fragments in its terminal moraine.

The broad principle was enunciated that wherever in Great Britain marine shells occur in glacial deposits at high levels, it can be proved, both by striæ and the transport of erratics, that the ice advanced on to the land from out of the sea. The shells on Three Rock Mountain, near Dublin, and in North Wales and Macclesfield, all from the Irish Sea; the shells in Cumberland transported from Solway Firth; those on the coast of Northumberland brought out of the North Sea; those of Airdree in Scotland, carried eastward from the bottom of the Clyde: and those from Caithness from Moray Firth were among examples adduced in proof of this principle. The improbability of a great submergence not leaving corresponding deposits in other parts of England was dwelt upon.

It was also held that there was insufficient evidence of more than one advance in the ice sheet, although halts occurred in its retreat. The idea of successive elevations and submergences with advances and retreats of the ice was disputed, and the author held that much of the supposed interglacial drift was due to subglacial water from the melting ice.

The last portion of the paper discussed the distribution of bowlders, gravels and clays, south of the glacial area. Much the greater part of England was believed to have been uncovered by land ice. The drift deposits in this area were shown to be the result in part of great fresh-water streams issuing from the melting ice sheet, and in part, of marine currents bearing icebergs during a submergence of some 450 feet. The supposed glacial drift about Birmingham, and the concentration of bowlders at Wolverhampton were regarded as due to the former agent, while the deposits at Cromer and the distribution of Lincolnshire chalk across southern England were due to the latter. The supposed esker at Hunstonton was held to be simply a sea-beach, and the London drift deposits to be of aqueous origin. Thus the rival theories of floating icebergs and of land glaciers were both true, the one for middle and southern England, the other for Scotland, Wales, and the north of England; and the line of demarcation was fixed by great terminal moraines.

The paper closed with an acknowledgment of indebtedness to the many geologists in England and Ireland who had rendered most generous assistance during the above investigation.

ART. LI.—*On certain fossiliferous Limestones of Columbia Co., N. Y., and their relation to the Hudson River Shales and the Taconic System;* by I. P. BISHOP.

THE age of the Taconic formation is a subject of so great geological interest that I need no other apology for the presentation of this paper on new discoveries of fossils in a metamorphic limestone on the western border of the Taconic slates in Columbia Co., N. Y., although my investigations are not yet completed.

The limestone is in the town of Chatham, just west of Canaan, and in that of Ghent, the town next south. It has along its eastern side the hydromica schist of the western Taconic belt of Emmons, the same that adjoins the Canaan fossiliferous limestone on its west side,* and the interval of slate between the two limestones is only six miles.

The limestone, or rather its eastern belt, outcrops at intervals from Chatham village on the southern border of the town, in a north-northeasterly direction, to the northeast corner of the town, and also south-southwesterly to Pulver's station, in the town of Ghent, following throughout nearly the course of the New York, Rutland & Montreal railroad.

A small exposure occurs at Chatham village in the bed of the Steine Kill, just below the trestle of the New York, Rutland and Montreal R. R.; again, two miles farther north at the railroad crossing, and thence along the track as far as "Black Rock Cut;" from there it lies to the east of the track at an average distance of a third of a mile, until near Rayville, when it crosses to the west and continues on that side nearly to Brainard's Station. South of Chatham it lies on both sides of the Hudson and Chatham R. R. as far as Pulver's Station. I have not had the opportunity to follow out its extension farther in either direction, but have no doubt that it can be traced much beyond these limits.

On the east side this limestone lies directly against the hydromica schist, and has the same northeasterly strike and southeasterly dip as the latter. The width of its exposure varies from a few feet to nearly a mile.

From Ghent northward, for about six miles, the limestone is bounded on the west by a belt of black, green, and red shales, having the same dip and strike. These shales contain fucoids and numerous graptolites, of species found in the Hudson River shales, together with two or more new species of brachiopods of the genus *Lingulops*. Parallel to this, and still farther west, lies a coarse gray sandstone of the upper part of the Hudson. This sandstone extends from Chatham village nearly to North Chatham. It is a mile wide at the former place and tapers to a thin strip south of the latter. Shales surround this on all sides.

Six miles to the west of Chatham there is another limestone belt with the same lithological characteristics, but having a general northwesterly strike. It extends from Ghent to Kinderhook Lake, where it appears to blend with the western belt,

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* This Journal, xxxi, 1886, pp. 241 and 248.

no shale intervening, as far as I have been able to find. The western arm is wrinkled into parallel anticlinals and synclinals. On the western side of the arm, two narrow belts of shale, having the lithological character of the graptolitic shales, are enclosed between these parallel ridges of limestone. Over the region from Ghent westward the axes of the folds dip to the north at an angle of 45° or 50°. At Kinderhook Lake there was some evidence of a southward dipping fold. The width of the western arm of limestone ranges from three-fourths of a mile to more than two miles.

Limestone outcrops also at Rider's Mills and near Malden in the northern part of the country. I have not yet had time to trace the western arm farther north than Kinderhook Lake, and therefore do not know to which belt the latter outcrop should be assigned.

The color of the limestone of both arms is bluish gray or dove-colored. It contains veins of calcareous spar which cross the surface irregularly, giving it a checkered appearance. It varies from massive thick-bedded limestone to calcareous shale. In all localities where I have observed it, there are brecciated layers present, made up of lenticular fragments of limestone, pieces of shale, and siliceous material. These usually contain limonite concretions, evidently changed from pyrites by oxidation and having nuclei of organic matter. Interspersed with the limestone are siliceous layers, both massive and thin-bedded, some of which are nearly pure sandstone or quartzite while others are calcareous. These do not resemble the Hudson River sandstones mentioned above in color, texture or appearance, and are undoubtedly distinct from them. It will be noticed that the series is similar to that described by Mather* at Great Neutin Hook, and probably belongs to the same system.

The fossiliferous localities are three in number and all are in the eastern belt. From the first, situated about midway between Chatham and Ghent, only crinoid stems have been taken. The second is situated at the crossing of the N. Y. & M. R. R., two miles north of Chatham; and the third a mile still farther north, on the farm of Mr. Joel Angell; and these two have furnished the fossils mentioned below. They were first noticed by me about April 1, 1886, at the R. R. crossing, and at the upper locality a few weeks later. Some layers of the rock are made up almost entirely of organic remains in which gasteropods predominate. There are, also, crinoid stems in abundance. Among the brachiopods there are several well-marked valves of *Leptœna sericea* and *Strophomena alternata.* The external markings of the gasteropods are so effaced by metamorphism and weathering that it is very difficult to distinguish species.

* Geology of N. Y., Pt. IV, 1843.

There are, however, several specimens of a slender *Murchisonia* which is probably *M. gracilis*, a single doubtful *Maclurea* and specimens of *Ophileta* in abundance. I have found one incomplete *Orthoceras*, but in too poor condition to be identified. Near the R. R. crossing, I obtained also a well-preserved bryozoan, a new species of the genus *Ptilodycta*.

While the two species of brachiopods which have been positively identified belong to both the Trenton and the Hudson River periods, the fact that the rocks of the latter do not include limestones in eastern New York, is strong evidence that these fossils are of Trenton age. The character of the associated genera and the appearance of the rock also strengthen this view.

If the limestones of the eastern and western belts are identical, as seems to be proved both by their connection at Ghent and by their similar lithological character, there can be no reasonable doubt that the limestone containing Trenton fossils immediately underlies the graptolitic shales of the Hudson River group.

The facts, as far as collected, are suggestive of a synclinal having the Trenton limestone outcropping on both sides, and with the eastern edge pushed over westward.

During the coming year I hope by mapping out the district carefully, and noting the strikes and dips, to get more exact information than I am able to present to-day.

Before closing I wish to express my indebtedness to Professor James Hall, the State Geologist and his assistants, who have identified for me the fossils found, and without whose aid this paper would not have been written.

LII.—*Crystallized Vanadinite from Arizona and New Mexico*; by S. L. PENFIELD.

THE occurrence of vanadinite in various localities in Arizona has been noticed by B. Silliman* and W. P. Blake,† and of crystals from the Black Prince Mine, Pinal Co., Arizona, by F. H. Blake.‡ The latter mentions, as the most common forms, prism and pyramids of the first order, prism of the second order and the basal plane. Through the kindness of Mr. L. Stadtmüller I have been able to examine a number of specimens from the above and other localities in Arizona and New Mexico which were in the collection of the late Professor B. Silliman. I have also examined a number of specimens in the collection of Professor Geo. J. Brush. The crystals from Pinal

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* This Journal, III, xxii, 198.

† This Journal, III, xxii, 410.

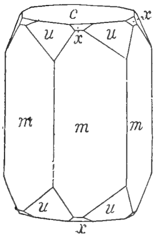
‡ This Journal, III, xxviii, 145.

Co., Arizona, merit especial attention; they are small, seldom over 1^{mm} in length, of a deep red color, and usually show the very simple combinations mentioned by Mr. Blake. A few highly modified crystals were found possessing pyramidal hemihedral forms which are of interest because these forms have rarely been observed in this species and show the close relation in habit between crystals of this mineral and apatite. They possess highly polished faces and are well suited for measurement. I have been able to identify the following forms:

m, $10\bar{1}0$, I
a, $11\bar{2}0$, $i\text{-}2$
h, $\pi\,21\bar{3}0$, $\frac{1}{2}(i\text{-}\frac{3}{2})$
c, 0001, O
r, $10\bar{1}2$, $\frac{1}{2}$
x, $10\bar{1}1$, 1
y, $20\bar{2}1$, 2
v, $11\bar{2}2$, $1\text{-}2$
s, $11\bar{2}1$, $2\text{-}2$
u, $\pi\,21\bar{3}1$, $\frac{1}{2}(3\text{-}\frac{3}{2})$

The hemihedral forms h and u have previously been observed, the former by C. Vrba* on crystals from Kappel, Carinthia, the latter by M. Websky† on crystals from Cordoba, Argentine Republic. Crystals from Pinal Co. showing these combinations are not uncommon. The most common combination is shown in fig. 1. The pyramid u can frequently be seen on both ends of the crystals, or where the free end shows, can be traced all around the crystals. Of pyramids of the first order x is the most common, but r or y, sometimes both, are frequently associated with it. Of pyramids of the second order s occurs frequently, v is seldom met with. Fig. 2 shows the occurrence of these planes which was observed on a single crystal; fig. 3 is a basal projection of the same. The hemihedral prism h is not common, but I have observed it on a number of crystals; on one attached by its side I was able to measure it three times on the edges which were available; it was in combination with m, a and c only. From the best measurement, $a \wedge s$ ($11\bar{2}0 \wedge 11\bar{2}1$) $=35°\ 6\frac{1}{2}'$, the axial ratio $a : c = 1 : 0{\cdot}71121$ is obtained. This agrees closely with the ratio given by Schabus,‡ $1 : 0{\cdot}71157$,

1.



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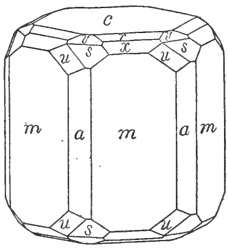

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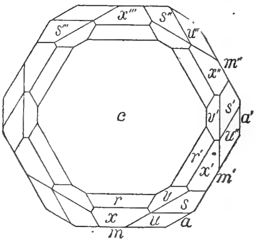

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* Zeitschr. Kryst., iv, 353. † Zeitschr. Kryst., v, 542. ‡ Pogg. Ann., c, 297.

and quite closely with that of Vrba,* 1:0·7112177. The measured angles are as follows :

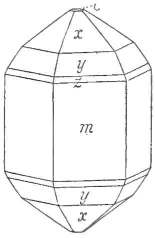
		Measured.	Calculated.	
			Vrba.	Author.
$a \wedge v$	$11\bar{2}0 \wedge 11\bar{2}2$	= 54° 30′	54° 33′	54° 35′
$m \wedge r$	$10\bar{1}0 \wedge 10\bar{1}2$	= 67° 42′	67° 39′	67° 41′
$m \wedge x$	$10\bar{1}0 \wedge 10\bar{1}1$	= 50° 33′	50° 34′	50° 36′
$m \wedge y$	$10\bar{1}0 \wedge 20\bar{2}1$	= 31° 20′	31° 18′	31° 20′
$x \wedge x$	$10\bar{1}1 \wedge 01\bar{1}1$	= 37° 2′	37° 2′	37° 0′
$x \wedge s$	$10\bar{1}1 \wedge 11\bar{2}1$	= 26° 36′	26° 38′	26° 36′
$s \wedge u$	$11\bar{2}1 \wedge 21\bar{3}1$	= 14° 0′	14° 2′	14° 1′
$m \wedge u$	$10\bar{1}0 \wedge 21\bar{3}1$	= 30° 55′	30° 50′	30° 52′
$c \wedge u$	$0001 \wedge 21\bar{3}1$	= 65° 17′	65° 19′	65° 17′
$m \wedge h$	$10\bar{1}0 \wedge 21\bar{3}0$	= 19° 9′	19° 6′	19° 6′

It will be seen that the angles agree closely with those calculated from the axial ratio of Vrba, also closely with those of the author.

The crystals contain only a trace of As_2O_5, which was proved by testing in the Marsh apparatus.

I have also examined crystals from the Sierra Grand Mine, Lake Valley, Grant Co., New Mexico. These are straw yellow in color and have the habit shown in fig. 4, many of them have a more prominent basal plane. The prism m is usually striated horizontally. The crystals react strongly for V_2O_5 and in the Marsh apparatus for As_2O_5, corresponding exactly to the description given by F. A. Genth and G. vom Rath† to the species named by them Endlichite (vanadium mimetite). The observed forms are given in fig. 4, $z = 30\bar{3}1$, 3. The crystals do not admit of very accurate measurement. From the best measurement $x \wedge x'$ ($10\bar{1}1 \wedge 01\bar{1}1$)=38° 12′ we obtain the ratio $a : c = 1 : 0·7495$. Other measured angles are :

4.



		Measured.	Calculated.	
			Endlichite.	Vanadinite, Author.
$x \wedge x'''$	$10\bar{1}1 \wedge \bar{1}011$	= 82° 3′	81° 45′	78° 47′
$y \wedge y'$	$20\bar{2}1 \wedge 02\bar{2}1$	= 51° 51′	51° 18′	50° 34′
$x \wedge y$	$10\bar{1}1 \wedge 20\bar{2}1$	= 18° 25′	19° 7′	19° 16′
$x \wedge z$	$10\bar{1}1 \wedge 30\bar{3}1$	= 27° 44′	28° 3′	28° 31′

It will be seen from the above that the angles do not agree well with the calculated angles of vanadinite. The presence of As_2O_5 in the mineral must therefore tend to very perceptibly increase the length of the vertical axis.

Mineralogical Laboratory, Sheffield Scientific School, June 16, 1886.

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* Loc. cit.

† Proc. Amer. Phil. Society, xxii, 367.

ART. LIII.—*The Viscosity of Steel and its Relations to Temper;* by C. BARUS and V. STROUHAL.

INTRODUCTORY.

IN an earlier number of the Journal, we expressed the belief that the qualities of retaining magnetism exhibited by steel would probably stand in relation to the viscous properties of the metal. In the present paper we make a first search for such a relation. The work is restricted to torsional viscosity because it usually exists in larger amount, and is much more accurately measurable than any of the other manifestations of viscosity. Possibly it may be brought more rationally into comparisons with magnetic phenomena. We therefore develop partially (i. e. so far as is necessary for our especial purposes) a new and very sensitive differential method for the study of torsional viscosity. Having applied it to steel, we compare the results obtained with the known behavior of permanent linear magnets, tempered under like conditions. During the course of the experiments we incidentally come upon certain ulterior results (viscosity of iron, glass).

In our magnetic comparisons we have endeavored to avoid prematurity. Many inferences of the original draught have been cropped. We do not wish to ignore the magnetic effect of the chemical changes of steel. We have merely endeavored to *circumscribe* the magnetic effect of carburation, by exploring the magnetic importance of certain mechanical properties of steel. To do this we have studied, abstractly as it were, the occurrence of permanent magnetism in a medium of continuously varying viscosity, without insisting on an inherent relation between retentiveness and viscosity.

Literary notes.—The necessary existence of viscosity in solids was pointed out, discovered, and its nature described by Weber;* but it is to Kohlrausch's† extensive researches that we owe the

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* Weber: Götting. Gelehrt. Anz., St. viii, 1835; Pogg. Ann., xxiv, p. 247, 1835; ibid., liv, p. 1, 1841; Comm. Soc. Götting., iii, p. 45, 1841. Weber's researches express the amount of viscous deformation in terms of time by a hyperbolic formula with three coustants.

† Kohlrausch: Pogg. Ann., cxix, p. 337, 1863; ibid., cxxviii, pp. 207, 399, 1866; ibid., clv, p. 579, 1875; ibid., clviii, p. 337, 1876. The author subjected fibers of a great number of substances to torsional, tensile and flexural stress, and discusses the amount of deformation in each case in its dependence on time and on temperature. The results are too elaborate to be excerpted here. The author finds it necessary to use exponential relations with three and even four constants to describe the results completely. In this place we advert, moreover, to the papers of Neesen (Pog. Ann., cliii, p. 498, 1874; ibid., clvii, p. 579, 1876; Wied. Ann., vii, 460, 1879), of Braun (Pogg. Ann., cxix, p. 337, 1876), of Wiedemann (Wied. Ann., vi, p. 496, 1879) which supply important details of critical discussion. Perhaps we may even add Pernet's well-known thermometric researches (Carl's Rep., xi, p. 257, 1875, and elsewhere).

bulk of our knowledge of to-day. A new method of research was indicated by Sir William Thomson,* which method was developed, independently of Thomson we believe, by Streintz † and by Schmidt.‡ Thomson § concisely defined the terms now in English use.

Plan of research.—We purposed at first to study the viscosity of steel from two distinct stand-points: one part of our work was to consider viscosity in its relations to temperature; the other part, viscosity in its relations to hardness. Indeed we have as yet no data of this kind for steel, at all. For other substances Kohlrausch‖ and after him Streintz¶ and Pisati** had already studied viscosity and temperature with some detail though in a direction differing somewhat from our own. Very recently, however, Schroeder†† of Freiburg has experimented in a line of research quite identical with the one upon which we had determined; and though his data do not include steel, the results obtained for other metals are sufficiently pronounced to make a special investigation of steel superfluous, at least so far as regards its *present* bearing on our work. Schroeder‡‡ finds "Der bei 100° begonnene Verlauf der Nachwirkung wird durch abkühlung des Drahtes auf Zimmertemperatur unterbrochen; nach erneuter Erwärmung auf 100° wird die vorher unterbrochene Drehung fortgesetzt." We pointed out§§ that in case of drawn metals, of quenched glass (Rupert's drops) and we inferred also in case of tempered steel, energy has been stored up in virtue of the rigidity of the material; and that on exposure to temperature (annealing), the available excess of stress is made to produce the observed viscous deformation precisely in the way in which Schroeder has found it for applied torsional stress.

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*Sir William Thomson: Phil. Mag. (IV), xxx, p. 63, 1865. Thomson refers the loss of energy of vibration to the existence of molecular friction.

† Streintz: Pogg. Ann., cliii, p. 387, 1874; Wien. Ber., lxix, part 2d, p. 355, 1874. Using a vibration method the author discusses elaborately the effect of viscosity on the logarithmic decrement.

‡ Schmidt: Wied. Ann., ii, pp. 48, 241, 1877, supplements Thomson's and Streintz's results, and is able to express logarithmic decrement in terms of time by Weber's formula of three constants. We may add Cohn (Wied. Ann., vi, p. 403, 1879), Hopkinson (Phil. Trans. 1877), Warburg (Wied. Ann., xiii, p. 141, 1881), Auerbach (Wied. Ann., xiv, p. 308, 1881), Kohlrausch (Pogg. Ann., cxxviii, 1886), Ewing (Phil. Trans., p. 545, 1885) and others who discuss viscosity as manifesting itself in phenomena of conductivity (Cohn), residual static charge (Hopkinson, Kohlrausch), magnetism (Auerbach, Warburg, Ewing and others).

§ Thomson: l. c.

‖ Kohlrausch: Pogg. Ann., cxxviii, p. 216, 1866; ibid. clviii, p. 371, 1876.

¶ Streintz; Wien. Ber. lxix, p. 337, 1874; also Schmidt, l. c.

** Pisati: Wien. Ber., lxxx, p. 427, 1879. Also Gaz. Chim. Ital., 1876, 1877.

†† Schroeder: Wied. Ann., xxviii, p. 369, 1876. ‡‡ Schroeder: l. c., p. 388.

§§ Bull. U. S. G. S., No. 14, p. 196, 1885; this Journal, xxxi, p. 452, 1866.

METHOD OF EXPERIMENTATION.

Apparatus.—1. For the reasons given the scope of this paper has been limited to a study of the viscosity of steel, in its relations to temper. We endeavor therefore to determine the difference of viscosity which corresponds to a given known difference of hardness. The following differential method of measurement, the principle of which can be made clear in a few words, naturally suggests itself:

Given a pair of steel wires one of which is always glass-hard, the other of known temper; let them be made the threads of a *bifilar suspension* provided with suitable means for the measurement of the angular motion of the line defined by the lower double-point of attachment, relatively to the upper line of attachment; finally let a twist of $+\psi$ be imparted to one steel wire, a twist of $-\psi$ to the other. If now the system be left to itself, and if the two wires be equally viscous the bifilar system (*cœt. par.*) will remain at rest. If on the other hand the viscosities be unequal, the lower free part of the bifilar will move around the vertical let fall from the upper part. The sign of this angular motion will be that of the twist of the wire of greater viscosity; its amount (*cœt. par.*) directly dependent on the difference of viscosity of the pair of wires under experiment. One of the forms of apparatus actually used is given in the annexed diagram, figures 1 and 2, the former on a scale of $\frac{1}{4}$. The couple of steel wires *awwg* and *axxg* to be tested, is fastened above to a massive piece of brass *ABC* and below to a similar piece *DEGF*. *ABC* is fixed firmly to the wall at some distance from it, and all incidental motion or displacement is registered by the mirror *M*, adjustable at pleasure by aid of the screw-arms *fed* and *bc*. *DEGF* is free to move under the influence of the bifilar couples and motion is similarly registered by the mirror *N* adjustable at pleasure by aid of the screw-arms *mlk* and *hi*. To keep the line of symmetry of the piece *DEGF* vertical, to deaden incidental vibrations, and to give general stability to the whole bifilar adjustment, we suspended a heavy lead disk *HQ* (5 lbs.) from the screw *r*. *HQ* is partially immersed in water contained in a glass bell-jar *ILK* also (adjustably) attached to the wall.

The steel wires are inserted and then fastened in the apparatus as follows: To keep the two steel wires (about 33^{cm} long) under a permanent strain of torsion, each is softened about 2^{cm} from the ends inward. The soft parts are then bent into a hook-like loop just large enough to slide over the screws of the little brass bolts *a* and *g*. Having fastened the lower ends by the bolt *g*, the upper ends are each twisted 180° against each other and then also fastened by the bolt *a*.

The ends of this twisted system are now to be secured to the blocks of brass *ABC* and *DEGF*. One method of fastening is given ($\frac{1}{2}$ actual size) in figure 2, the parts of which are lettered similarly to figure 1. The two wires, *w* and *x*, are pressed firmly against a little rectangular piece of steel, *o* by aid of the bolt *pp′* and the nut *qq′*. The bolt is provided with a square hole near its head, through which *o* and the steel wires may easily be passed. A little pin prevents *o* from rotating around the axis of the screw, thus diminishing liability to breakage. In the apparatus figured it is necessary to slide the bolts *pp′* over the wires *w*, *x*, before the torsion is applied by fastening *a*.

In a more convenient form of apparatus, perhaps, we replace the brass blocks *ABC* and *DEGF* by little hand vises, the axle of the lower one of which has been perforated and fitted with a screw subserving the purposes of *r* in the figure. By aid of a disc of lead vertical symmetry of the whole apparatus is here also maintained.

The advantages of this form of apparatus, apart from our own special purposes, is this, that

1, 2.

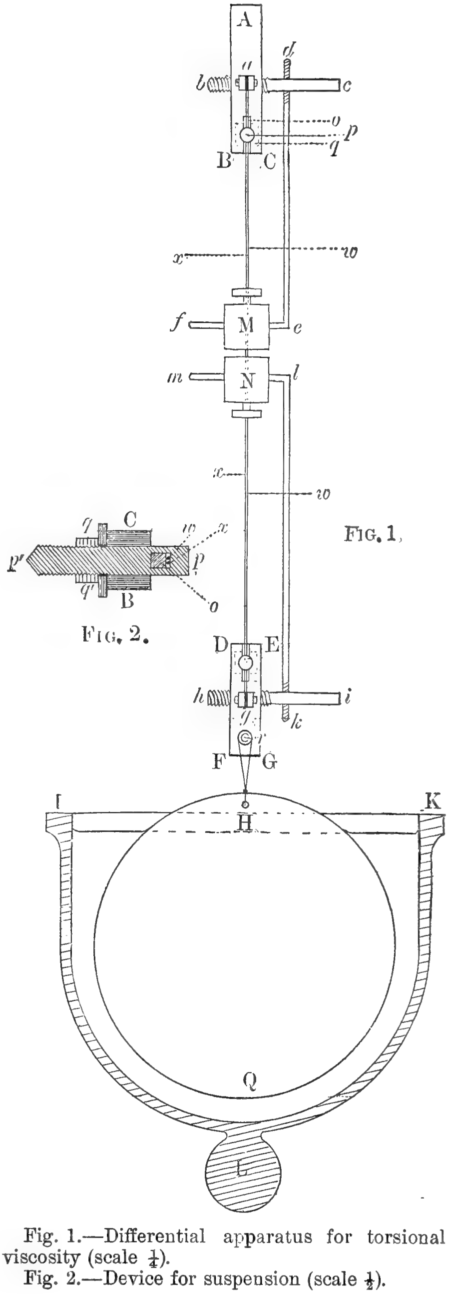

Fig. 1.—Differential apparatus for torsional viscosity (scale $\frac{1}{4}$).

Fig. 2.—Device for suspension (scale $\frac{1}{2}$).

with a single adjustment, the viscous movement can be traced with extreme accuracy for an indefinite length of time. There is no doubt that in some of the cases examined such motion will demonstrably exist even for a year after the torsion has been imparted. Kohlrausch's method is an absolute method; but his wire must be twisted and untwisted once for each observation. The method of logarithmic decrement is difficult of interpretation, is really a complex method and limited to short intervals of time.

In experimenting with glass it was necessary to modify the apparatus so that twists less than $\psi=180°$ could be applied. This is easily done by perforating the screw of the upper bolt and passing the glass fiber through the hole. Torsion in any amount may then be applied to the projecting fiber.

2. Our second (tubular) apparatus combines with the advantages of the one just sketched, the ulterior desideratum of enabling the observer to follow the viscous detorsion immediately after applying stress; and therefore also of exhibiting the effect of positive torsion immediately succeeding negative torsion and vice versa; or of studying the effect produced by an indefinite number of alternations of the sign of the twist. In the second form of apparatus the wire is introduced into a narrow tube just large enough to surround it. The tube is fixed above and fastened to the wire below. Twist is imparted to the wire and through it to the tube. The observations, in other respects, are conducted as above.

Method of Observation.—In both forms of apparatus, angles are registered by Gauss' method of telescope* and scale. We secure extreme accuracy by using two mirrors, one of which (stationary) furnishes a reliable fiducial mark for the other (movable). These mirrors are easily so adjusted that their respective scale-images appear *simultaneously* in the field of the telescope one above the other and intersected by the same cross-hair. Indeed it would not be difficult to arrange this device that the stationary image could be used as a vernier on the moving image.

Method of Tempering.—The wires used (Stubs' steel) were hardened galvanically as described elsewhere.† To Professor H. A. Rowland, who placed his dynamo-electric machine at our disposal for this purpose, and favored us with the benefit of his advice during almost the entire afternoon, we owe our very cordial thanks.

The annealing was effected by drawing the glass-hard wires through a zone of constant temperature by clockwork.‡

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* Three wood screws, the head of one of which is planed, of another hollowed out conically, make a good adjustable plane-dot-slot arrangement.

† Bull. U. S. G. S., No. 14, p. 29; Wied. Ann., xi, p. 932, 1880.

‡ This Journal, xxxii, p. 279, 1886.

Elimination of Errors.—1. The steel wires to be used in these experiments are all about $0{\cdot}1^{\mathrm{cm}}$ in thickness. Hence to determine the condition of equilibrium or motion in the torsional apparatus described, it is necessary to consider the respective moments of the bifilar couple (M_b), of the torsional couple (M_T) and of the flexural couple (M_f), by which the movable end is actuated.

The moment of the bifilar couple has the well-known form*

$$\mathrm{M}_b=\tfrac{1}{4}\frac{ll'}{L}mg\sin\varphi \quad . \quad . \quad . \quad (1)$$

where l and l' are respectively the distance apart of the upper ends and the lower ends of the bifilar wires, L the vertical distance and φ the horizontal angle between the lines l and l', mg the weight of the whole suspended adjustment. To mg should be added one-half the weight of the wires.

The moment of the torsion couple is $M_\tau=\tau\varphi$, where τ is the sum of the torsional coefficients of the wires. This applies because the sum of the stored torsional moments, for $\varphi=0$, is $\psi+(-\psi)=0$. We may give the equation M_τ an experimentally convenient form by substituting for τ the approximate value* derived in elastics. We obtain

$$M_T=\frac{2\pi}{5}\,\frac{E\rho^4}{L}\varphi \quad . \quad . \quad . \quad (2)$$

where ρ is the radius of the steel wires used, E the C. G. S. value† of the modulus of elasticity of steel.

The moment of the flexural couple is more involved. If p be the distance apart of vertical planes passing through the bifilar wires, if f be the horizontal component of the flexural force, then the flexural couple is $M_f=fp$. We have however by geometry, $p=(ll'\sin\varphi)/s$, where s is the sum of the horizontal projections of the wires. We have moreover given us in elastics

$$E=\frac{4}{3}f\,\frac{L^3}{\pi\rho^4}\,\frac{1}{\frac{s}{2}},$$

and therefore the couple in question becomes

$$M_f=\frac{3\pi}{8}\,\frac{ll'\rho^4}{L^3}E\sin\varphi \quad . \quad . \quad , \quad (3)$$

The equations 1, 2 and 3 enable us to choose the dimensions of the wire and of the apparatus as well as to select conditions

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* C. F. Maxwell, ii, p. 108, 1881; Kohlrausch Leitfaden, p. 167, 1884.

† Poisson's coefficient is in the following estimate taken at $\frac{1}{4}$.

‡ If E' be the current technical modulus referred to the kilogram and square millimeter, $E=E'g\times10^5$.

of experiment such that the torsional couple may alone be effective. The following are extremely unfavorable phases of the best available values, in question:

$$l=l'<0{\cdot}2^{\text{cm}};\ L>25^{\text{cm}};\ m<2500^{\text{g}};\ \varphi<0{\cdot}2^{\circ};\ \rho=0{\cdot}041^{\text{cm}};\ E=2\times10^{12}\ (ml^{-1}t^{-2}).$$

In view of the small values of φ it is sufficient to compare the coefficients only. We obtain nearly

$$M_b : M_T : M_f = 1000 : 280000 : 20.$$

Hence it appears that in the case of the chosen dimension the most unfavorable effect of the bifilar and flexural couples combined, is less than 0·4 per cent of the torsional couple. Moreover the torsional couple becomes more predominant as the angle of deviation, φ, increases so that no serious inaccuracy from the discrepancies here enumerated need be apprehended.

2. When we operate with glass-hard steel, we encounter so many mechanical difficulties, that the conditions postulated in the foregoing analysis can not be immediately assumed. We can not, for instance, adjust the tensions of the two wires precisely to equality. Nor is it easy so to store the permanent torsion that the parallelism of the lines joining the upper and lower points of suspension remains intact. Under these circumstances flexural and bifilar couples may have very different values from the ones accepted and the moments, as a whole, will form a complex aggregate. Although it is improbable that the flexural and bifilar discrepancies will exceed the limits of error investigated, it is none the less desirable to determine them by direct experiment. This can be done with convenience and great accuracy.

Let the water be removed from the jar *ILK* and the system put in vibration around a vertical and in such a way that the angle φ remains small. Then the circumstances of motion are given by

$$\frac{4\pi^2K}{T^2}=\tfrac{1}{4}\frac{ll'}{L}mg+\tau+\frac{\delta M_f}{\delta\varphi},$$

where K is the moment of inertia of the bifilar body, T the time of a complete vibration. If we replace the steel wires by threads for which τ and $\delta M_f/\delta\varphi$ are zero, we may find the value of the bifilar coefficient in terms of the other two. We cite the following typical experiment:

Steel wires: $T_s=0{\cdot}025$ sec.; $L=26^{\text{cm}}$; $l<0{\cdot}1^{\text{cm}}$;
Brass capillary wire: $T_b=0{\cdot}35$ sec.; $L=30^{\text{cm}}$; $l=0{\cdot}2^{\text{cm}}$; $l'=0{\cdot}3^{\text{cm}}$.

If we reduce the results for capillary brass wire to the L and l which obtain for steel, we deduce $T_b 40$ sec.$=0{\cdot}$ Hence the bifilar coefficient is less than 0·4 per cent of the combined torsional and flexural coefficients, in very unfavorable values of the chosen dimensions. This experimental result agrees with the one calculated above.

3. The following static method is better, being exhaustive and final. Let the lower ends of the pair of identical steel wires, A and B, be fastened with the bolt. Let rotation at this end be temporarily checked. Then we may store like degrees of torsion by twisting the upper ends of the wires in the following three ways:

a. Let the wire A be twisted $+360°$ and then fastened to B. Left to itself the upper end of the system will rotate $-180°$ so that the residual torsion of A is $+180°$; of B is $-180°$. The total couple actuating the bifilar body then is of the form $\pm M_b + M_T \pm M_f$.

b. Let the wires A and B be twisted $+180°$ and $-180°$ respectively and then fastened together. Left to itself the upper end of the system will not move. The residual torsion is therefore the same as in case *a*; but the total couple here actuating the bifilar body is $M_T \pm 0$. This is the case premised in the analysis which introduces this paragraph.

c. Let the wire B be twisted $-360°$ and then fastened to A. Left to itself the upper end will rotate $+180°$, so that the residual torsions on A and B are the same as in cases *a* and *b*; but the total couple which in case of viscous motion actuates the bifilar body has now the form $\mp M_b + M_T \mp M_f$.

This is the device: We are able to *commutate*, as it were, the combined flexural and bifilar couples relative to the torsional couple of *fixed* sign. In the results below this test is frequently applied and we will there show that for the chosen dimensions the torsion couple need alone be considered.

4. In the case of the tubular apparatus the present precautions are at once superfluous. Here each wire is introduced into the tube and compared with the next wire introduced under like circumstances. The tubular apparatus is specially adapted for the investigation of viscous detorsion in its dependence on the applied torsional stress, as well as on time. But the same work may also well be done with the bifilar.

The viscous effect of the relative sections of the wires and allied observations, with a bearing on viscosity proper, can more expediently be made after the experimental data have been communicated. It is convenient to insert a few remarks on the rigidity of efficient parts of the above apparatus here. If the tubular adjustment d be the diameter of the wire, d_1 and D_1 the diameters of the tube, if L symbolize the effective length, ψ the amount of stored twist, G the rigidity, we have, in view of the equal couples,

$$\psi\frac{\pi d^4 G}{32L}=\psi_1\frac{\pi(D^4_1-d^4_1)G_1}{32L_1} \quad \ldots\ldots \quad (1)$$

Now in order to make sharp comparisons on the viscosity of solids, in order to investigate its dependence both on time and on stress, the apparatus is so to be adjusted that *like stresses produce like strains* in the substances compared. Hence put $\psi=\psi_1$, whence

$$\frac{d^4}{D^4_1-d^4_1}=\frac{G_1L}{GL_1}=\text{const.}\ \frac{L}{L_1} \quad \ldots\ldots \quad (2)$$

This applies to the bifilar apparatus for $d_1=0$. The equation (2) shows at once how to study viscosity under conditions in which like stresses produce like strains upon like sectional areas of the viscous solids compared.

Notation.—In Bulletin 14 we used the word "retentiveness" in the restricted German sense to designate magnetic stability, or the property in virtue of which a magnet resists such influences as temperature, percussion, time. The common English use of the term is much broader than this and refers to residual induction* in a general way. Fortunately the context of our paper is sufficiently clear and does not admit of serious misapprehension. Inasmuch as measurement of total induction has not yet fallen properly within the scope of our work, we purposely withhold many obvious allusions to magnetic permeability. We moreover retain the term permanent magnetization to denote the magnetic moment *per unit of mass* of a permanently saturated rod, for the sake of uniformity with our earlier notation. Its ratio to magnetic intensity is therefore the density of steel.

To avoid troublesome circumlocution we use the adjective "viscous" with the very broad meaning of "pertaining to viscosity." Such expressions as "viscous phenomena" though not elegant are convenient. Similarly we often speak without confusion of "linear magnetization" where "magnetization of a linear rod" is meant.

Experimental Data.

Introductory explanations.—The following tables, Nos. 1 to 26, contain results for the viscosity of steel in different states of temper. To these are appended other tables of a miscellaneous kind. For convenience of comparison we insert a little index. The apparatus used in obtaining the data are designated by the Roman numerals in the first column. Nos. I to IV are

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* Mr. Ewing proposes a new and very elegant extension of the current use of "retentiveness." He defines it as "resistance to any change of magnetic state which (magnets) exhibit whenever the magnetic field in which they are placed suffers any change."- -*Phil. Trans.*, ii, 1885, p. 526.

different forms of the bifilar adjustment; No. V is the tubular instrument. The index also contains the numbers of the rods or fibers joined together to make the bifilar couple and other information readily understood. Glass and iron fibers are lettered. It is to be remembered that in the steel measurements one of the pair of wires is always glass-hard, the other annealed as specified.

INDEX TO TABLES.

I. EXPERIMENTS PROPER.

Temper of the rod coupled with glass-hard.

Apparatus No.	Annealed 20°.	Annealed 100°.	Annealed 190°.
I.	Table 1, Rods 47, 48.	Table 5, Rods 3, 4. Table 5A, Rods 43, 44.	
II.	Table 2, Rods 1, 2.	Table 6, Rods 5, 6. Table 6A, Rods 45, 46.	Table 10, Rods 11, 12.
III.		Table 7, Rods 7, 8.	Table 13, Rods 13, 14. Table 13A, Rods 19, 20
IV.		Table 8, Rods 9, 10.	Table 14, Rods 15, 16.

Apparatus No.	Annealed 360°.	Annealed 450°.	Annealed 1000° (soft).
I.		Table 19, Rods 23, 24.	Table 23, Rods 27, 28 (soft).
II.	Table 16, Rods 17, 18.	Table 20, Rods 25, 26.	Table 24, Rods 29, 30 (commercial drawn).
III.			Table 25, Rods 31, 32 (commercial annealed).
IV.	Table 18, Rods 21, 22.		Table 26, Rods 33, 34 (annealed from glass-hard).

II. MISCELLANEOUS EXPERIMENTS.

Apparatus No.	Glass. *a.*	Glass. *b.*	Iron drawn. *c, k.*
I.	Table 27, Rod 35.	Table 28, Rods 36, 42.	
II.			Table 29, Rod 37. Table 30A, Rod 50.
III, IV.			
V.			

Apparatus. No.	Iron soft. *g, d.*	Brass tube (thick). *e.*	Brass tube (thin). *f.*	Misc. soft steel.
I.	Table 30, Rod 38.			
II.				
III.				Table 34, Rods 51, 52.
IV.				
V.		Table 31, Rods 39, 40.	Table 32, Rod 41.	

Experiments proper.—In tables 1 to 26, R denotes the distance between mirror and scale, L the efficient length of the steel (bifilar) wires, l the distance apart of the upper and lower points of suspension. ψ (in degrees) is the stored torsion, imparted to the whole length (30^{cm}) of wire, positively or negatively as specified, whereas φ_0 (in radians) is the amount of angular motion (differential detorsion) of the bifilar system due to viscosity per centimeter of length of the system of two steel wires. Positive values of ψ and φ_0 refer to the same angular direction, and φ_0 is arbitrarily put zero (to fix the coördinates) at the time one hour after the twist ψ has been imparted. This is the best conveniently available method for comparing the divers data. Other methods would have compelled us to wait for the subsidence of motion, certainly several months in each case. Moreover, to obtain extreme degrees of accuracy, it is necessary to study viscosity under circumstances of constant temperature, and in a place where the viscous yielding may proceed unaccompanied by tremor or vibratory motion of the apparatus. For these nice experiments we are not now prepared.

The tables furthermore contain the date, the number of hours (h_0) elapsed since the beginning of the experiment and the arbitrary deflection, φ (radians per centimeter of bifilar length),* for each of the times specified. The radius of the wires is given under ρ. Finally the sense of the couples actuating the bifilar body is indicated by τ (torsion), b (bifilar), f (flexure).

TABLE 1.—APPARATUS I.

$R=217^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 47, glass-hard, $\psi=-180°$; No. 48, glass-hard, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
21/8, $6^h\,08^m$	(*)	0·00	(*)	25/8, $9^h\,05^m$	0·615	91·92	0·156
6 21	0·438	0·22	−0·030	7 01	0·632		
7 08	0·468	1·00	+0·000	26/8, $9^h\,10^m$	0·653	114·52	0·194
22/8, $9^h\,57^m$	0·543	15·82	0·075	4 08	0·670		
5 58	0·552	23·83	0·084	27/8, $9^h\,11^m$	0·695	140·26	0·237
6 54	0·555	24·77	0·087	7 36	0·714		
23/8, $9^h\,08^m$	0·568	39·00	0·100	28/8, $9^h\,21^m$	0·734	164·00	0·276
12 31	0·572	42·38	0·104	6 55	0·755		
5 37	0·577	47·48	0·109	29/8, $10^h\,12^m$	0·780	188·11	0·318
24/8, $9^h\,17^m$	0·588	67·12	0·126	6 17	0·792		
5 13	0·600						

* Adjusted τ—b—f.

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* In practice ϕ is the angle between the normals of the upper and lower mirror divided by the efficient length of wire.

TABLE 2.—APPARATUS II.

$R=203^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 1, glass-hard, $\psi=+180°$; No. 2, glass-hard, $\psi=-180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^6$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
11/6, $4^h\,30^m$	(*)	0·00	(*)	12/6, $8^h\,35^m$	1·920	16·08	0·015
5 00	1·896	0·50	−0·009	9 25	1·922	16·92	0·017
5 30	1·905	1·00	±0·000	10 10	1·922	17·67	0·017
6 15	1·909	1·75	+0·004	1 5	1·926	20·58	0·021
7 00	1·910	2·50	0·005	2 20	1·926	21·83	0·021
7 33	1·913	3·06	0·008	5 00	1·926	24·50	0·021
				5 50	1·926	25·33	0·021
				8 30	1·926	28·00	0·021
				13/6, $8^h\,30^m$	1·926	40·00	0·021

* Adjusted $\tau-b-f$.

TABLE 5.—APPARATUS I.

$R=209^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 3, glass-hard, $\psi=-180°$; No. 4, annealed, 100°, 10^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
24/6, $8^h\,30^m$	(*)	0·00	(*)	26/6, $8^h\,23^m$	0·755	47·88	0·561
9 00	0·139	0·50	−0·055	12 04	0·767	51·57	0·573
9 30	0·194	1·00	±0·000	3 17	0·778	54·78	0·584
10 56	0·277	2·43	+0·083	6 50	0·792	58·33	0·598
11 49	0·312	3·32	0·118	27/6, $8^h\,50^m$	0·825	72·33	0·631
12 37	0·338	4·12	0·144	3 04	0·834	78·57	0·640
1 52	0·373	5·37	0·179	28/6. $8^h\;9^m$	0·857	95·65	0·663
3 15	0·401	6·75	0·207	11 29	0·857	98·98	0·663
4 01	0·418	7·52	0·224	5 22	0·859	104·87	0·665
4 55	0·433	8·42	0·239	29/6, $8^h\;7^m$	0·864	118·63	0·670
6 5	0·453	9·58	0·259				
25/6, $8^h\,41^m$	0·619	24·18	0·425				
11 35	0·640	27·08	0·446				
5 25	0·682	32·92	0·488				
6 58	0·692	34·47	0·498				

* Adjusted $\tau-b-f$.

TABLE 5 A.—APPARATUS I.

$R=217^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 43, glass-hard, $\psi=-180°$; No. 44, annealed 100°, 9^h, $\psi=+180°$. $2\rho=0{\cdot}082$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10_3$
8/8, $5^h\,00^m$	(*)	0·00	(*)	14/8, $9^h\,11^m$	−0·447	140·19	1·618
5 17	1·265	0·28	−0·125	5 12	−0·509		
6 17	1·127	1·28	+0·013	15/8, $1^h\,34^m$	−0·635	167·07	1·790
7 33	1·043	2·55	+0·097	6 35	−0·664		
9/8, $9^h\,05^m$	0·736	16·08	0·404	16/8, $1^h\,27^m$	−0·755	191·18	1·909
11 56	0·686	18·93	0·454	6 55	−0·783		
1 06	0·664	20·10	0·476	17/8, $9^h\,22^m$	−0·858	213·15	2·028
7 05	0·579	26·08	0·561	6 55	−0·918		
10/8, $10^h\,02^m$	0·427	41·03	0·713	18/8, $9^h\,15^m$	−0·984	236·36	2·139
1 19	0·388	44·32	0·752	5 29	−1·015		
6 20	0·333	49·33	0·807	19/8, $9^h\,03^m$	−1·066	260·82	2·220
11/8, $10^h\,06^m$	0·184	69·15	1·001	6 35	−1·094		
1 15	0·147			20/8, $9^h\,16^m$	−1·136	285·00	2·289
7 06	0·085			6 44	−1·162		
12/8, $9^h\,22^m$	−0·042	92·43	1·220	21/8, $9^h\,07^m$	−1·196	304·12	2·336
5 30	−0·117						
13/8, $9^h\,09^m$	−0·245	116·10	1·422				
1 28	−0·285						
4 41	−0·316						

* Adjusted, $\tau+b+f$.

TABLE 6.—APPARATUS II.

$R=203^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 5, glass-hard, $\psi=-180°$; No. 6, annealed 100°, 9^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date	$\phi\times10^3$	h_0	$\phi_0\times10^3$
13/6, $9^h\ 15^m$	(*)	0·00	(*)	14/6, $9^h\ 00^m$	2·393	23·75	0·486
10 15	1·907	1·00	0·000	10 30	2·401	25·25	0·494
11 15	2·031	2·00	0·124	1 3	2·407	27·80	0·500
12 05	2·100	2·83	0·193	2 6	2·409	28·85	0·502
1 25	2·162	4·17	0·255	3 50	2·409	30 58	0·502
3 16	2·247	6·02	0·340	5 27	2·412	32·20	0·505
5 05	2·296	7.83	0·389	† 6 53	2·412	33·60	0·505
6 50	2·345	9·58	0·438				
7 30	2·358	10·25	0·451				

* Adjusted, $\tau-b-f$.

† Subequent movement apparently retrograde.

TABLE 6A.—APPARATUS II.

$R=202^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 45, glass-hard, $\psi=-180°$; No. 46, annealed, 100°, 10^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
8/8, $6^h\ 10^m$	(*)	0·00	(*)	14/8, $9^h\ 11^m$	0·440	139·03	1·020
6 19	1·502	0·15	−0·062	5 12	0·399		
7 32	1·422	1·37	+0·018	15/8, $1^h\ 34^m$	0·316	165·91	1·133
9/8, $9^h\ 55^m$	1·195	15·75	0·245	6 35	0·298		
12 31	1·169	18.35	0·271	16/8, $1^h\ 27^m$	0·234	190 02	1·218
7 52	1·098	25·70	0·342	6 55	0·211		
10/8, $10^h\ 02^m$	1·007	39·87	0·433	17/8, $9^h\ 22^m$	0·163	211·98	1·299
1 19	0·993	43·15	0·447	6 55	0·119		
6 19	0·948	48·15	0·492	18/8, $9^h\ 15^m$	0·070	235·20	1·382
11/8, $10^h\ 45^m$	0·853	68·19	0·615	5 29	0·046		
1 14	0·833			19/8, $9^h\ 03^m$	0·007	259·65	1·440
7 05	0·789			6 35	−0·008		
12/8, $9^h\ 22^m$	0·709	91·26	0·756	20/8, $9^h\ 16^m$	−0·040	283·83	1·488
5 30	0·658			6 44	−0·056		
13/8, $9^h\ 09^m$	0·576	114·93	0·891				
1 28	0·544						
4 41	0·526						

* Adjusted, $\tau+b+f$.

TABLE 7.—APPARATUS III.

$R=400^{\mathrm{cm}}$; $L=27^{\mathrm{cm}}$; $l<0{\cdot}2^{\mathrm{cm}}$. Rods: No. 7, glas-shard, $\psi=-180°$; No. 8, annealed, 100°, 10^{h}, $\psi=+180°$. $2\rho=0{\cdot}082^{\mathrm{cm}}$.

Date.	$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
1/7, $12^{\mathrm{h}}\,40^{\mathrm{m}}$	(*)	0·00	(*)
1 20	3·122	0·67	−0·128
2 45	2·994	2·08	±0·000
3 25	2·956	2·76	+0·038
4 37	2·903	3·95	0·091
5 39	2·869	4·98	0·125
6 59	2·832	6·32	0·162
2/7, $9^{\mathrm{h}}\,22^{\mathrm{m}}$	2·627	20·70	0·367
1 46	2·578	25·10	0·416
5 11	2·554	28·52	0·440
3/7, $8^{\mathrm{h}}\,20^{\mathrm{m}}$	2·435	43·67	0·559
12 14	2·397	47·57	0·597
6 30	2·331	53·83	0·663
4/7, $9^{\mathrm{h}}\,47^{\mathrm{m}}$	2·233	73·10	0·800
12 09	2·208		
3 08	2·183		
6 00	2·153		
5/7, $8^{\mathrm{h}}\,40^{\mathrm{m}}$	2·061	95·80	0·965
12 00	2·033		
4 44	1·992		
6/7, $8^{\mathrm{h}}\,40^{\mathrm{m}}$	1·890	120·61	1·137
1 53	1·854		
5 16	1·826		
7/7, $8^{\mathrm{h}}\,53^{\mathrm{m}}$	1·730	144·55	1·300
1 30	1·691		
5 16	1·660		
8/7, $9^{\mathrm{h}}\,16^{\mathrm{m}}$	1·547	168·59	1·485
12 43	1·515		
5 48	1·465		
9/7, $8^{\mathrm{h}}\,35^{\mathrm{m}}$	1·366	192·02	1·657
12 11	1·339		
5 18	1·307		
10/7, $8^{\mathrm{h}}\,07^{\mathrm{m}}$	1·225	215·87	1·798
12 09	1·200		
5 20	1·162		
11/7, $9^{\mathrm{h}}\,08^{\mathrm{m}}$	1·080	236·47	1·914

* Adjusted, $\tau+b+f$.

TABLE 8.—APPARATUS IV.

$R=308^{\mathrm{cm}}$; $L=26^{\mathrm{cm}}$; $l<0{\cdot}2^{\mathrm{cm}}$. Rods: No. 9, glass-hard, $\psi=-180°$; No. 10, annealed, 100°, 10^{h}, $\psi=+180°$. $2\rho=0{\cdot}082^{\mathrm{cm}}$.

Date.	$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
1/7, $1^{\mathrm{h}}\,40^{\mathrm{m}}$	(*)	0·00	(*)
2 46	1·185	1·10	0·000
3 26	1·213	1·77	0·028
4 39	1·246	2·82	0·061
5 40	1·265	4·00	0·080
7 00	1·290	5·33	0·105
2/7, $9^{\mathrm{h}}\,23^{\mathrm{m}}$	1·420	19·72	0·236
1 48	1·459	24·13	0·274
5 12	1·482	28·53	0·297
3/7, $8^{\mathrm{h}}\,22^{\mathrm{m}}$	1·577	42·70	0·392
12 15	1·605	46·58	0·420
6 30	1·641	52·83	0·456
4/7, $9^{\mathrm{h}}\,49^{\mathrm{m}}$	1·729	72·12	0·574
12 10	1·747		
3 09	1·770		
6 01	1·791		
5/7, $8^{\mathrm{h}}\,41^{\mathrm{m}}$	1·876	94·81	0·718
12 00	1·899		
4 45	1·935		
6/7, $8^{\mathrm{h}}\,42^{\mathrm{m}}$	2·027	119·63	0·874
1 54	2·063		
5 17	2·088		
7/7, $8^{\mathrm{h}}\,54^{\mathrm{m}}$	2·185	143·58	1·034
1 32	2·222		
5 18	2·249		
8/7, $9^{\mathrm{h}}\,18^{\mathrm{m}}$	2·362	167·61	1·206
12 43	2·385		
5 49	2·427		
9/7, $8^{\mathrm{h}}\,37^{\mathrm{m}}$	2·524	191·04	1·366
12 11	2·547		
5 19	2·581		
10/7, $8^{\mathrm{h}}\,07^{\mathrm{m}}$	2·655	210·45	1·470

* Adjusted, $\tau-b-f$

TABLE 10.—APPARATUS II.

$R=200^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 11, glass-hard, $\psi=-180°$; No. 12, annealed, 190°, 2^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
1/7, $4^h\ 00^m$	(*)	0·00	(*)	2/7, $9^h\ 20^m$	2·215	17·33	0·625
4 35	2·913	0·58	−0·073	1 45	2·133	21·75	0·707
5 36	2·767	1·60	+0·073	5 09	2·080	25·15	0·760
6 58	2·655	2·97	0·185	3/7, $8^h\ 19^m$	1·891	40·32	0·949
				12 12	1·843	44·20	0·997
				6 28	1·757	50·47	1·083

* Adjusted, $\tau+b+f$.

TABLE 13.—APPARATUS III.

$R=370^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 13, glass-hard, $\psi=-180°$; No. 14, annealed, 190°, 1^h; $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10_0$
14/6, $12^h\ 30^m$	(*)	0·00	(*)	21/6, $8^h\ 22^m$	3·732	169·91	2·692
1 10	1·025	0·67	−0·065	12 15	3·763		
2 05	1·198	1·58	+0·108	5 44	3·810		
3 51	1·402	3·35	0·312	†7 17	3·823		
4 21	1·448	3·85	0·358	22/6, $9^h\ 10^m$	3·913	193·38	2·856
5 29	1.525	4·98	0·435	1 18	3·943		
6 55	1·606	6·42	0·516	2 20	3·948		
7 51	1·648	7·35	0·558	6 42	3·980		
15/6, $9^h\ 04^m$	2·022	20·57	0·932	23/6, $8^h\ 30^m$	4·056	214·86	2·971
10 00	2·042	21·50	0·952	12 43	4·077		
11 15	2·073	22·75	0·983	5 42	4·111		
1 10	2·121	24·67	1·031	24/6, $9^h\ 02^m$	4·197	240·38	3·132
2 58	2·165	26·47	1·075	12 39	4·222		
4 17	2·195	27·78	1·105	4 58	4·248		
5 41	2·223	29·18	1·133	25/6, $8^h\ 44^m$	4·335	264·13	3·266
6 18	2·233	29·80	1·143	11 38	4·351		
16/6, $8^h\ 00^m$	2·467	48·26	1·460	†5 31	4·383		
9 32	2·492			26/6, $8^h\ 29^m$	4·448	289·18	3·385
1 07	2·556			12 10	4·467		
3 19	2·597			3 12	4·483		
5 50	2·638			6 52	4·504		
17/6, $8^h\ 34^m$	2·861	73·43	1·878	27/6, $8^h\ 52^m$	4·575	311·49	3·502
10 29	2·899			3 06	4·609		
12 43	2·942			28/6, $8^h\ 11^m$	4·699	335·87	3·631
3 35	2·995			11 30	4·720		
5 29	3·043			5 25	4·744		
6 45	3·066			29/6, $8^h\ 11^m$	4·811	361·44	3·754
18/6, $11^h\ 45^m$	3·236	99·02	2·181	3 46	4·854		
4 39	3·283			5 52	4·866		
†6 09	3·293			30/6, $8^h\ 53^m$	4·943	384·41	3·872
19/6, $9^h\ 07^m$	3·410	120·92	2·346	12 26	4·962		
12 19	3·432			5 25	4·982		
2 25	3·445			1/7, $8^h\ 47^m$	5·028	404·28	5·028
5 50	3·458						
20/6, $8^h\ 53^m$	3·567	145·23	2·515				
10 53	3·581						
3 26	3·622						
7 44	3·652						

* Adjusted, $\tau-b-f$. † Re-adjusted after this observation.

TABLE 13A.—APPARATUS III.

$R=400^{cm}$: $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 19, glass-hard, $\psi=-180°$; No. 20, annealed, 190°, 1^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
11/7, $3^h\ 20^m$	(*)	0·00	(*)
4 10	−0 037	0·83	−0·037
4 20	±0·000	1·00	±0·000
5 22	+0·161	2 03	+0·161
7 00	0·329	3·67	0·329
12/7, $7^h\ 37^m$	0·913	16·28	0·913
7 55	†	16·58	†
9 02	0 466	17·70	0·960
10 55	0·523	19·58	1·017
5 27	0 696	26·12	1·190
13/7, $8^h\ 29^m$	0·952	41·15	1·446
12 29	0·999	45 15	1·493
5 08	1·061	49 80	1·555
14/7, $8^h\ 54^m$	1·230	69·49	1·765
12 51	1·270		
4 41	1·314		
15/7, $10^h\ 46^m$	1·491	94·27	2·013
4 26	1·548		
16/7, $9^h\ 18^m$	1·695	118·32	2·232
1 44	1·740		
5 55	1·780		
17/7, $8^h\ 47^m$	1·899	141·90	2·438
12 53	1·940		
6 02	1·992		
18/7, $8^h\ 44^m$	2·096	164·25	2·617
2 26	2·151		
19/7, $9^h\ 39^m$	2·304	189·73	2·829
12 20	2·331		
5 12	2·371		

* Adjusted $\tau+b+f$.

† Adjusted $\tau-b-f$.

TABLE 14.—APPARATUS IV.

$R=300^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 15, glass-hard, $\psi=-180°$; No. 16, annealed, 190°, 1^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
11/7, $4^h\ 25^m$	(*)	0·00	(*)
4 42	−0·210	0·28	−0·175
4 55	−0·143	0·50	−0·108
5 25	−0·035	1·00	±0·000
7 00	+0·153	2·58	+0·188
12/7, $7^h\ 38^m$	0·685	15·22	0·720
5 28	0·937	25·05	0·972
13/7, $8^h\ 29^m$	1·179	40 07	1·214
12 29	1·222	44 07	1·257
5 09	1·280	48·73	1·315
14/7, $8^h\ 54^m$	1·434	68·40	1·508
12 52	1·473		
4 42	1 512		
15/7, $10^h\ 47^m$	1·670	93·20	1·730
4 26	1·720		
16/7, $9^h\ 19^m$	1·849	117·26	1·919
1 45	1·885		
5 58	1·917		
17/7, $8^h\ 49^m$	2·022	140·84	2·093
12 54	2·052		
6 03	2·099		
18/7, $8^h\ 45^m$	2·198	163·35	2·256
2 47	2·243		
19/7, $9^h\ 40^m$	2·378	188·66	2·444
12 21	2·419		
5 13	2·429		
20/7, $8^h\ 32^m$	2·517	209·68	2·562
11 40	2·538		

* Adjusted $\tau-b-f$.

TABLE 16.—APPARATUS II.

$R = 200^{cm}$; $L = 27^{cm}$; $l < 0·2^{cm}$. Rods: No. 17, glass-hard, $\psi = -180°$; No. 18, annealed, 350°, 1^h, $\psi = +180°$. $2\rho = 0·082^{cm}$.

Date.	$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
4/7, 10^h 35^m	(*)	0·00	(*)
10 53	−2·767	0·30	−0·267
12 08	−2·457	1·55	+0·043
3 07	−2·118	4·53	0·382
5 59	−1·929	7·40	0·570
5/7, 8^h 39^m	−1·423	22·07	1·076
11 59	−1·318	25·40	1·181
5 43	−1·187	31·13	1·312
6/7, 8^h 40^m	−0·882	46·08	1·617
1 52	−0·773	51·28	1·726
5 15	−0·703	54·67	1·796
7/7, 8^h 50^m	−0·455	74·59	2·127
1 26	−0·367		
5 15	−0·295		
8/7, 9^h 15^m	−0·056	98·66	2·513
12 42	+0·007		
5 47	0·089		
9/7, 8^h 34^m	0·274	122·09	2·826
12 10	0·321		
5 17	0·383		
10/7, 8^h 05^m	0·545	145·93	3·092
12 08	0·589		
5 19	0·643		
11/7, 9^h 08^m	0·797	171·67	3·348
11 34	0·821		
5 21	0·881		
6 59	0·892		
12/7, 7^h 36^m	0·993	193·93	3·533
5 26	1·072		
13/7, 8^h 27^m	1·163	218·10	3·686
12 27	1·180		
5 08	1·215		
14/7, 8^h 53^m	1·299	242·20	3·823
12 48	1·323		
4 40	1·348		
15/7, 10^h 45^m	1·446	267·00	3·965
4 25	1·483		
16/7, 9^h 17^m	1·565	286·70	4·065

* Adjusted $\tau - b - f$.

TABLE 18.—APPARATUS IV.

$R = 316^{cm}$; $L = 26^{cm}$; $l < 0·2^{cm}$. Rods: No. 21, glass-hard, $\psi = -180°$; No. 22, annealed, 360°, 1^h, $\psi = +180°$. $2\rho = 0·082^{cm}$.

Date.	$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
14/6. 2^h 45^m	(*)	0·00	(*)
3 52	1·155	1·12	0·025
4 22	1·250	1·62	0·120
5 30	1·415	2·75	0·285
6 55	1·558	4·17	0·428
7 53	1·632	5·13	0·502
15/6, 9^h 05^m	2·198	18·33	1·068
†10 00	2·231	19·25	1·101
11 16	2·273	20·52	1·143
1 11	2·340	22·43	1·210
3 00	2·400	24·25	1·270
4 16	2·442	25·57	1·312
5 42	2·478	26·95	1·348
6 19	2·490	27·57	1·360
16/6, 8^h 02^m	2·802	46·03	1·785
9 33	2·837		
1 09	2·928		
3 20	2·978		
5 50	3·028		
17/6, 8^h 35^m	3·302	71·19	2·296
10 30	3·349		
12 44	3·405		
3 36	3·465		
5 30	3·503		
6 45	3·531		
18/6, 8^h 53^m	3·741	95·12	2·667
11 45	3·770		
4 40	3·829		
†6 10	3·850		
19/6, 9^h 09^m	4·000	118·69	2·904
12 19	4·026		
2 27	4·037		
5 51	4·071		
20/6, 8^h 54^m	4·193	143·01	3·105
10 59	4·211		
3 25	4·250		
7 45	4·286		

* Adjusted $\tau - b - f$. † Re-adjusted.

TABLE 18.—Concluded.

Date.		$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$	Date.		$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
21/6,	$8^h\ 23^m$	4·374	167·66	3·290	26/6,	$8^h\ 30^m$	5·143	286·87	4·048
	12 15	4·403				*1 28	5·177		
	5 45	4·447				6 53	5·213		
	7 16	4·456			27/6,	$8^h\ 53^m$	5·303	309·25	4·196
22/6,	$9^h\ 11^m$	4·541	191·61	3·434		3 07	5·350		
	1 19	4·558			28/6,	$8^h\ 13^m$	5·450	333·64	4·346
	4 13	4·573				11 31	5·471		
	6 43	4·583				5 26	5·508		
23/6,	$8^h\ 30^m$	4·666	214·22	3·569	29/6,	$8^h\ 12^m$	5·595	359·19	4·505
	12 43	4·699				3 45	5·647		
	5 42	4·732				5 53	5·662		
24/6,	$9^h\ 03^m$	4·829	238·15	3·722	30/6,	$8^h\ 54^m$	5·740	382·18	4·629
	12 40	4·853				12 27	5·757		
	4 59	4·873				5 26	5·780		
25/6,	$8^h\ 45^m$	4·973	261·88	3·875	1/7,	$8^h\ 48^m$	5·848	402·05	5·848
	11 39	4·997							
	5 30	5·044							

* Re-adjusted.

TABLE 19.—APPARATUS I.

$R=217^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 23, glass-hard, $\psi=-180°$; No. 24, annealed, 450°, 1^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.		$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$	Date.		$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
21/7,	$2^h\ 50^m$	(*)	0·00	(*)	29/7,	$8^h\ 56^m$	−0·673	189·80	3·814
	3 17	3·276	0·45	−0·176		12 36	−0·714		
	4 44	2·901	1·90	+0·198		4 22	−0·758		
	5 21	2·805	2·52	0·294	30/7,	$8^h\ 52^m$	−0·937	213·85	4·085
	6 13	2·698	3·38	0·401		1 05	−0·991		
22/7,	$8^h\ 40^m$	1·924	17·83	1·175		4 07	−1·030		
	11 58	1·798	21·13	1·301	31/7,	$9^h\ 28^m$	−1·210	237·82	4·345
	5 30	1·606	26·67	1·493		12 36	−1·249		
	7 10	1·552	28·33	1·547		3 55	−1 281		
23/7,	$7^h\ 49^m$	1·307	40·98	1·792	2/8,	$9^h\ 38^m$	−1·639	286·13	4·768
	12 30	1·141	45·67	1·958		1 11	−1·672		
	3 31	1·072	48·68	2·027		4 05	−1·696		
24/7,	$9^h\ 13^m$	0·769	69·91	2·393	3/8,	$9^h\ 38^m$	−1·807	310·22	4·926
	12 52	0·702				1 14	−1·826		
	4 10	0·647				4 18	−1·844		
26/7,	$8^h\ 53^m$	0·126	117·40	3·019	4/8,	$1^h\ 31^m$	−1·947	336·12	5·055
	12 07	0·081				4 23	−1·962		
	3 42	0·033			5/8,	$1^h\ 36^m$	−2·052	360·67	5·162
27/7,	$8^h\ 49^m$	−0·146	141·60	3·290		5 25	−2·073		
	12 26	−0·193			6/8,	$9^h\ 12^m$	−2·139	382·48	5·257
	4 04	−0·235				5 26	−2·175		
28/7,	$9^h\ 11^m$	−0·423	166·03	3·564	7/8,	$9^h\ 15^m$	−2·225	407·13	5·346
	1 07	−0·468				6 41	−2·268		
	4 17	−0·503							

* Adjusted $\tau+b+f$.

TABLE 20.—APPARATUS II.

$R=198^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 25, glass-hard, $\psi=-180°$; No. 26, annealed, 450°, 1^h, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
15/6, $12^h\ 50^m$	(*)	0·00	(*)
1 07	1·968	0·28	−0·282
1 15	2·046	0·42	−0·204
1 30	2·152	0·67	−0·098
1 45	2·239	0·92	−0·011
2 55	2·475	2·08	+0·225
4 15	2·648	3·42	0·398
5 39	2·776	4·82	0·526
6 17	2·825	5·45	0·575
16/6, $7^h\ 56^m$	3·447	19·10	1·197
9 30	3·506	20·67	1·256
1 06	3·632	24·27	1·382
3 17	3·703	26·45	1·453
5 49	3·780	28·98	1·530
17/6, $8^h\ 33^m$	4·134	49·06	2·035
10 26	4·191		
12 41	4·258		
3 31	4·337		
5 26	4·378		
6 44	4·410		
18/6, $8^h\ 48^m$	4·656	72·98	2·471
11 43	4·690		
4 38	4·759		
6 07	4·778		
19/6, $9^h\ 05^m$	4·953	96·53	2·741
12 10	4·982		
2 23	4·998		
5 50	5·031		
20/6, $8^h\ 12^m$	5·170	120·71	2·963
10 52	5·179		
3 24	5·232		
7 42	5·270		
21/6, $8^h\ 20^m$	5·364	145·55	**3·177**
12 15	5·401		
†5 40	5·466		
7 19	5·478		
22/6, $9^h\ 08^m$	5·573	169·47	**3·355**
1 16	5·597		
4 10	5·617		
6 40	5·632		
23/6, $8^h\ 27^m$	5·717	192·10	**3·499**
12 40	5·748		
5 41	5·781		
24/6, $9^h\ 00^m$	5·880	216·01	**3·660**
12 37	5·909		
4 55	5·941		
25/6, $8^h\ 42^m$	6·045	239·76	**3·820**
11 36	6·068		
5 28	6·111		
26/6, $8^h\ 27^m$	6·206	264·29	**3·989**
12 05	6·227		
6 50	6·283		
27/6, $8^h\ 51^m$	6·367	287·11	**4·140**
3 02	6·412		
28/6, $8^h\ 08^m$	6·516	311·51	**4·326**
11 29	6·535		
5 24	6·678		
29/6, $8^h\ 09^m$	6·662	337·07	**4·451**
3 43	6·714		
5 50	6·728		
30/6, $8^h\ 52^m$	6·811	350·08	**4·577**
12 29	6·825		
5 24	6·845		
1/7, $8^h\ 39^m$	6·910	379·82	**4·660**

* Adjusted, $\tau-b--f$.

† Re-adjusted.

TABLE 23.—APPARATUS I.

$R=215^{\mathrm{cm}}$; $L=27^{\mathrm{cm}}$; $l<0{\cdot}2^{\mathrm{cm}}$. Rods: No. 27, glass-hard, $\psi=-180°$; No. 28, soft, $\psi=+180°$. $2\rho=0{\cdot}082$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
9/6, $2^{\mathrm{h}}\ 30^{\mathrm{m}}$	(*)	0·00	(*)
3 10	1·652	0·67	−0·118
3 13	1·677	0·71	−0·093
3 21	1·730	0·85	−0·040
3 47	1·860	1·28	+0·090
4 00	1·910	1·50	0·140
4 10	1·940	1·67	0·170
4 32	2·004	2·03	0·234
5 15	2·102	2·75	0·332
5 35	2·140	3·08	†0·370
6 00	2·185	3·50	0·415
6 15	2·210	3·75	0·440
10/6, $8^{\mathrm{h}}\ 50^{\mathrm{m}}$	2·938	20·09	1·227
9 35	2·964		
9 55	2·973		
10 15	2·985		
10 45	3·002		
11 20	3·023		
11 45	3·038		
12 17	3·056		
10/6, $1^{\mathrm{h}}\ 30^{\mathrm{m}}$	3·100	26·64	1·448
2 15	3·128		
3 05	3·153		
4 00	3·191		
4 40	3·214		
5 25	3·238		
6 25	3·265		
†7 40	3·287		
8 05	3·296		
8 20	3·304		
11/6, $8^{\mathrm{h}}\ 06^{\mathrm{m}}$	3·542	47·34	1·895
9 28	3·571		
10 21	3·588		
10 45	3·598		
11 45	3·617		
12 11	3·628		
2 30	3·680		
3 48	3·709		
4 50	3·733		
5 50	3·753		
7 00	3·777		
7 35	3·787		
12/6, $8^{\mathrm{h}}\ 37^{\mathrm{m}}$	3·989	71·44	2·318
9 25	4·005		
10 10	4·017		
1 05	4 076		
2 55	4·108		
4 58	4·146		
5 50	4·162		
8 30	4·202		
13/6, $8^{\mathrm{h}}\ 40^{\mathrm{m}}$	4·376	95·89	2·702
10 15	4·405		
12 06	4·436		
1 25	4·458		
3 16	4·485		
5 07	4·517		
6 50	4·545		
7 30	4·556		
14/6, $9^{\mathrm{h}}\ 04^{\mathrm{m}}$	4·736		
10 30	4·757	120·33	3·046
1 00	4·796		
2 06	4·813		
3 50	4·836		
5 27	4·853		
6 52	4·866		
7 50	4·873		
15/6, $9^{\mathrm{h}}\ 00^{\mathrm{m}}$	4·990	143·30	3·272
10 00	4·998		
11 15	5·015		
1 05	5·037		
2 55	5·060		
4 15	5·071		
5 38	5·082		
6 15	5·086		
16/6, $7^{\mathrm{h}}\ 58^{\mathrm{m}}$	5·205	166·22	3·488
9 30	5·223		
1 05	5·265		
3 15	5·285		
5 48	5·310		
17/6, $8^{\mathrm{h}}\ 30^{\mathrm{m}}$	5·455	191·54	3·758
10 26	5·485		
12 40	5·520		
3 30	5·550		
5 27	5·570		
7 43	5·590		
18/6, $8^{\mathrm{h}}\ 46^{\mathrm{m}}$	5·705	215·31	3·970
11 43	5·720		
4 37	5·760		
6 08	5·775		
19/6, $9^{\mathrm{h}}\ 04^{\mathrm{m}}$	5·880	238·52	4·125
12 09	5·890		
5 50	5·915		
20/6, $8^{\mathrm{h}}\ 50^{\mathrm{m}}$	6·010	263·18	4·272
10 50	6·023		
3 23	6·055		
7 40	6·080		
21/6, $8^{\mathrm{h}}\ 20^{\mathrm{m}}$	6·140	287·88	4·408
12 15	6·160		
5 38	6·200		
7 19	6·210		
22/6, $9^{\mathrm{h}}\ 07^{\mathrm{m}}$	6·270	311·80	4·525
1 16	6·290		
4 09	6·305		
6 40	6·315		
23/6, $8^{\mathrm{h}}\ 28^{\mathrm{m}}$	6·375	334·44	4·633
12 40	6·405		
5 40	6·430		

* Adjusted, $\tau-b-f$.

† Re-adjusted.

TABLE 24.—APPARATUS II.

$R=202^{cm}$; $L=28^{cm}$; $l<0·2^{cm}$. Rods: No. 29, glass-hard, $\psi=-180°$; No. 30, commercial, drawn, $\psi=+180°$. $2\rho=0·082^{cm}$.

Date.	$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
21/7, $10^h\ 45^m$	(*)	0·00	*
11 50	2·263	1·08	0·000
12 18	2·206	1·55	0·057
2 03	2 045	3·30	0·218
3 52	1·926	5·12	0·337
5 22	1·847	6·62	0·416
22/7, $8^h\ 40^m$	1·416	21·92	0·847
11 58	1·341	25·22	0·922
5 31	1·217	30·77	1·046
7 44	1·187	32·98	1·076
23/7, $7^h\ 50^m$	0·984	45·08	1·279
12 32	0·896	49·78	1·367
3 33	0·851	52·80	1·412
24/7, $9^h\ 16^m$	0 624	74·03	1·737
12 53	0·499		
4 12	0·456		
26/7, $8^h\ 55^m$	−0·025	121·53	2·292
12 08	−0·011		
3 47	−0·051		
27/7, $8^h\ 51^m$	−0·211	145·71	2·516
12 27	−0·255		
4 05	−0·293		
28/7, $9^h\ 20^m$	−0·487	170·18	2·781
1 09	−0·517		
4 18	−0·550		
29/7, $8^h\ 56^m$	−0·709	193·90	3·012
12 39	−0·749		
4 23	−0·788		
30/7, $8^h\ 54^m$	−0·957	217·96	3·269
1 06	−1·010		
4 07	−1·050		
31/7, $9^h\ 42^m$	−1 230	242·01	3·526
12 37	−1·263		
3 57	−1·297		
2/8, $9^h\ 39^m$	−1·644	290·23	3·934
1 12	−1·677		
4 06	−1·693		
3/8, $9^h\ 40^m$	−1·780	314·33	4·049
1 15	−1·784		
4 19	−1·793		
4/8, $1^h\ 32^m$	−1 872	340·22	4·139
4 24	−1·880		
5/8, $1^h\ 37^m$	−1·965	364·77	4·237
5 25	−1·982		
6/8, $9^h\ 13^m$	−2·044	386·59	4·324
5 27	−2·078		
7/8, $9^h\ 17^m$	−2·133	411·24	4·412
6 42	−2·165		

* Adjusted, $\tau+b+f$.

TABLE 25.—APPARATUS III.

$R=370^{cm}$; $L=27^{cm}$; $l<0·2^{cm}$. Rods: No. 31, glass-hard, $\psi=-180°$; No. 32, commercial, softened, $\psi=+180°$. $2\rho=0·082^{cm}$.

Date.	$\phi \times 10^3$	h_0	$\phi_0 \times 10^3$
22/7, $9^h\ 00^m$	(*)	0·00	(*)
9 08	0·949	0·13	−0·249
11 59	0·331	2·98	+0·368
5 32	0·099	8·53	0·600
7 11	−0·193	10·18	0·893
23/7, $7^h\ 52^m$	−0 643	22·87	1·343
12 35	−0·794	27·58	1·494
3 25	−0·880	30·42	1·580
24/7, $9^h\ 21^m$	−1·246	48·35	1·946
12 57	−1·320	51·95	2·020
4 16	−1·384	55·27	2·084
26/7, $8^h\ 57^m$	−1·993	99·31	2·749
12 10	−2·050		
3 49	−2·105		
27/7, $8^h\ 54^m$	−2·305	123·51	3·055
12 30	−2·356		
4 08	−2·404		
28/7, $9^h\ 26^m$	−2·612	147.98	3·355
1 11	−2·658		
4 20	−2·695		
29/7, $8^h\ 59^m$	−2·875	171·72	3·624
12 42	−2·923		
4 28	−2·974		
30/7, $8^h\ 57^m$	−3·160	195·80	3·913
1 10	−3·217		
4 17	−3·261		

* Adjusted $\tau+b+f$.

TABLE 26.—APPARATUS IV.

$R=314^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 33, glass-hard, $\psi=-180°$; No. 34, annealed at 1000°, $\psi=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.		$\phi\times10^3$	h_0	$\phi_0\times10^3$
21/7,	$4^h\,15^m$	(*)	0·00	(*)
	4 43	1·249	0·47	−0·149
	5 23	1·089	1·13	+0·010
	5 45	1·022	1·50	0·077
	6 12	0·957	1·95	0·142
22/7,	$8^h\,42^m$	0·162	16·45	0·937
	12 00	0·042	19·75	1·057
	5 33	−0·250	25·30	1·249
	7 12	−0·185	26 95	1·284
23/7,	$7^h\,53^m$	−0·448	39·63	1·547
	12 36	−0 559	44·35	1·658
	3 36	−0·628	47·35	1·727
24/7,	$9^h\,23^m$	−0·024	68·64	2·082
	12 59	−0·985		
	4 19	−1·038		
26/7,	$9^h\,05^m$	−1·540	116·14	2·685
	12 14	−1·581		
	3 52	−1·633		
27/7,	$9^h\,03^m$	−1·807	140·35	2·951
	12 34	−1·851		
	4 10	−1·895		
28/7,	$9^h\,29^m$	−2·081	164·79	3·222
	1 16	−2·125		
	4 23	−2·159		
29/7,	$9^h\,02^m$	−2·324	189·18	3·467
	12 45	−2·367		
	4 31	−2·409		
30/7,	$9^h\,00^m$	−2·583	212·61	3·730
	1 13	−2·633		
	4 22	−2·673		
31/7,	$9^h\,52^m$	−2·850	236·61	3·982
	12 41	−2·882		
	4 01	−2·912		
2/8,	$10^h\,02^m$	−3·264	284·95	4·389
	1 24	−3·291		
	4 10	−3·312		
3/8,	$9^h\,47^m$	−3·423	308.93	4·534
	1 22	−3·436		
	4 24	−3·442		
4/8,	$1^h\,38^m$	−3·548	334·78	4·654
	4 26	−3·560		
5/8,	$1^h\,40^m$	−3·660	359·31	4·768
	5 27	−3·675		
6/8,	$9^h\,14^m$	−3·733	381·10	4·855
	5 28	−3 777		
7/8,	$9^h\,22^m$	−3·829	405·80	4·946
	6 43	−3·863		

* Adjusted $\tau+b+f$.

Remarks on the Tables.—In experimenting with couples of two glass-hard wires, or with couples in which one of the wires is annealed at 100°, the degree of hardness of the harder wire is an exceedingly important factor. Hence these curves (tables 5, 5A, 6, 6A, 7, 8) appear under a variety of forms. Only tables 5A, 6A, 7, 8 are used in the digest constructed below. The results in tables 19, 24, 26 change their curvature after August 1st. Since the same error is found in all the wires then examined it is probably a result of temperature. When minutely examined (cf. table 23, for instance), the curves show a sinuous outline which is quite marked and probably also due to temperature, or to tremors. If the curves for stated temperatures and times of annealing fail to coincide it is due to differences in the tempers of the glass-hard wires, to similar differences in the tempers of the annealed wires, to preëxisting strains accidentally imparted to one wire or the other, to lack of perfect uniformity of temper throughout the efficient lengths, to unavoidable inequalities of the sectional areas of the pairs of wires. The last-named error probably also effects the curvature. Viscous rotation of the arms which carry the mirrors, or yielding of the cement, is nil and is not to be apprehended, since the fixed mirror is a fiducial mark for the movable mirror. In the above work we do not indicate the amount of permanent torsion left in each wire after the experiment is finished. Though an important desideratum, it does not fall within the scope of this paper. The effect of temperature on twisted systems of pairs of identical steel wires we shall probably investigate later and then discuss the amount of detorsion due to annealing at stated temperatures and times. The soft ends introduce no serious error because soft steel is more viscous than hard steel. The amount of twist registered is that between the upper and lower points of attachment. The included wires must be of uniform hardness.

The fact that an effect of the bifilar and flexural components is wholly absent in these results is proved by table 13A, in which the curve for $\tau+b+f$ is followed without break of continuity by the curve $\tau-b-f$, and the total curve is practically identical with the locus for table 13. It is proved, moreover, by tables 1, 2, in which couples of glass-hard wires show no greater difference than is at once attributable to unavoidable differences of hardness; and by table 34, in which $\tau+b+f$ and $\tau-b-f$ produce practically identical zero-effects on two soft wires. It is generally proved by the distribution of the 50 rods examined in a diagram of viscosity conformably with the respective tempers of the rods. If a couple of one hard and one soft rod possessed a smaller total of viscosity than a couple of two hard rods, then the bifilar and flexural couples might produce an effect in the former case and not in the latter. The absence of all effect in the case of two soft rods as well as in the case of two hard rods shows that the discrepancy in question is nil. The important bearing of this result will be indicated below.

[To be concluded.]

ART. LIV.—*Some Remarks upon the Journey of André Michaux to the high Mountains of Carolina, in December*, 1788, *in a Letter addressed to Professor Asa Gray;* by C. S. SARGENT.

HAVING recently returned from a somewhat extended excursion through that portion of the mountain region of North and South Carolina which lies about the head waters of the Savannah River,—the scene, I have reason to believe, of André Michaux's perilous and interesting mountain journey made in the winter of 1788–89, and which, so far as I can learn, has not been visited again until this year by a botanical traveler,

—you will permit me, I hope, to invite your attention to a few remarks suggested by my journey. In doing this I venture to remind you of the fact, not without interest to the younger generations of botanists, that it is just forty-five years (or nearly half the century which separates us from the time when André Michaux was engaged in exploring the flora of North America), since you made known to the botanical world through the pages of this Journal some of the results of your first journey in the Carolina Mountains and traced the foot-steps of your botanical predecessor in that field.*

The principal object of Michaux, as will appear later, was to gather living plants of *Magnolia cordata.* This tree, although still preserved and now very generally distributed in gardens, has never so far as I am aware, been found growing naturally since the days of the Michauxs. The object of my journey was to rediscover it, where Michaux was thought to have found it, and so throw some light upon its specific character and geographical distribution. But, before entering upon any discussion of this subject, it is desirable to determine if possible what plant Michaux set out to collect, and the exact region visited by him for this purpose. Fortunately the manuscript diary of Michaux's travels in North America, presented by his son, F. A. Michaux, to the American Philosophical Society, aids us here.

Michaux left Augusta on the 21st of November, 1788. On the 24th he arrived at Washington, in Wilkes County, Georgia, where a serious attack of fever detained him until the 29th. He reached the head of the Savannah River on the second of December and then ascended its western fork, the Tugalo, for several days. Here he secured the services of a Cherokee guide and crossed some of the spurs of the Blue Ridge into the valley of the Keowee River, camping on the banks of that stream on the evening of the 7th. The remainder of his journey will best be described in his own words.

"Le 8 Decembre, 1788, à mesure que nous approchions de la source du Keivi, les chemins devinrent plus difficiles. Notre marche fut de . . . . et deux miles avant d'y arriver je reconnus le *Magnolia montana* qui a été nommé *M. cordata* ou *auriculata* par Bartram. Il y avait en ce lieu une petite cabane habitée par une famille de sauvage Cherokees. Nous nous arretames pour y camper et je courrus faire des recherches. Je recueillis un nouvel arbuste a f. dentelées rampant sur la montagne à peu de distance de la riv. Le temps changea et nous eumes de la pluie toute la nuit, quoique nous fassions a

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* Notes of a Botanical Excursion in the mountains of North Carolina, etc., by Asa Gray, M.D., vol. xlii, No. 1, December, 1841.

l'abri d'un gros Pinus Strobus, nos habits, nos couvertures furent trempés et traversés. J'allai vers milieu de la nuit dans la Cabane des sauvages qui pouvait à peine contenir la famille composée de huit personnes, hommes et femmes. Il y avait de plus six gros chiens qui augmentoient la malpropreté de cet appartement et l'incommodité. Le feu etoit placé au mileu sans ouverture au haut de la cabane pour laisser sorter la fumée, il y en avait cependt assez po. recevoir la pluye au travers la couverture de cette maison. Un sauvage m'offrit son Lit qui etait une Peau d'Ours et vint prendre ma place aupres du feu. Mais enfin incommodé par les Chiens qui se mordoient continuellent pour avoir leur place au feu, je retournay au camp, la pluye ayant cessé.

Ce lieu qui l'on nomme la source de Keivi cet ainsi improprement nommé, c'est la junction de deux autres rivi ou gros Torrents qui viennent se revunir en ce lieu et n'ont pas été nommés sinon Branches de Keivi. Le q. nous partimes guide par mon sauvage po. visiter les plus hautes montagnes et aller à la source de ce torrent qui me parut le plus escarpé. Il fallut passer des précipices et des torrents couverts d'arbes ou dix fois nos chevaux s'enfoncerent et furent en danger de perir. Nous remontames jusqu'a une cascade ou la bruit de l'eau en tombant ressemblait a des coups eloignes de Mousquets. Les sauvages disent que l'on voit paroitre en ce lieu des feur la nuit. Je desirai y camper, mais la neige qui survint et le vent etait si froid que nous cherchames le bas d'une montagne moins exposé au froid et un lieu plus garni d'herbes po. nos chevaux. La nuit fut horriblement froide, il n'y avait pas en ce lieu bois de Pin po. entretenir le feu qui brulait mal à cause de la neige qui tomba à plus reprises. Nos couvertures couvertes de neige devenoient roides de gelée peu après avoir été chaufées.

Le 10 Decembre. Je visitay plusi montagnes, sur la pente et dans les lieux bas nous arrachames le *Magnolia cordata* la journee fut employée plus particulieremt à la recherche de cet arbe.

Le onze dud. il gela considerablement et l'air fut clair et tres vif. Je remarquai une suite de hautes montagnes qui se prolongeaient de l'Ouest a l'Est et ou la gelée s'etoit fait peu sentir a l'expositoin du soleil. Je recueillis un Juniperus (repens) que je n'avoir pas encore remarqué dans les parties meridionales des Etats Unis; mais il faut observer que je vis sur ces montagnes plusieurs arbes des parties septentionales telsque le Betula nigra, Cornus alternifolia, Pinus Strobus, Abies, Spruce, etc. Nous traversames un espace d'environ trois miles dans les Rhododendrons maximum. Je reviens camper avec mes quides à la Tête des Keivi (head of Kiwie) et je recueillis une grande quantité de cet arbuste a f. denticulées trouvé le jour que j'arrivay. Je ne le rencontray sur aucune des autres montangnes. Les sauvages du lieu me dirent que les feuilles avoient bon gout etant machées et que l'odeur en était agréable en les froissant, ce que ie trouval effectivement.

Direction pour trouver cet arbuste.—La Tête du Keivi est la jonction de deux torrents considerables qui coulent par cascades des hautes montagnes. Cette jonction se fait dans une petite plaine oa il y avait autrefois une ville ou plutot un village de Cherokees. En descendant de la junction de ces deux torrents ayant la rivi à gauche et les montagnes qui regardent le Nord à droite, on trouve à environ 30 à 50 toises de ce confluent un senti formé par les Chasseurs sauvages, il conduit à un ruisseau ou l'on reconnait les vestiges d'un village par les Pèchers qui subsistent au milieu des Brouss. En continuant ce sentier on arrive aussitot sur les montagnes et l'on trouve cet arbuste qui couvre le sol avec l'Epigea repens.

Le 12 Decembre, 1788. Je visitay les montagnes exposées au sud en revenant, car les provisions etoient si avancés, qu'il y eut un Dejeuner três sobre. Je recueillis beaucoup de *Magn. cordata* en un meilleur état que ceux des jours precedents."

The entry, made in the journal on the 3d of December, suggests that *M. auriculata* (*M. Fraseri* Walter) must have been the object of Michaux's search at this time, and not the *M. cordata* of his flora. The younger Bartram twelve years before had visited the Cherokee country, crossing the mountains on to the waters of the Tennessee River, and had discovered his *Magnolia auriculata* first on the mountains between the Tugalo and the Keowee, and then in greater abundance and perfection on what he supposed was the highest peak of the Cherokee mountains, probably either Hogback or Whiteside, and which he named Mount Magnolia in honor of his discovery.* Michaux doubtless had heard of this new Magnolia at the time of his visit to the Bartrams in 1787, and as his route was now almost identical with that followed by William Bartram, there seems to be little doubt that it was Bartram's Magnolia, and not the *Magnolia cordata* of his flora, which he was in pursuit of. The fact that Michaux mentions in his journal under date of June 14, 1787, when he was on the Keowee River, the discovery of a new Magnolia "que je nomme Magnolia (Hastata)" and which from the locality must have been Bartram's plant, is no reason why a year later he may not have spoken of it as the "mountain Magnolia named by Bartram, *M. cordata ou auriculata.*" This discovery of June 14th, judging from the brief mention in this Journal, made less impression upon Mi-

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* William Bartram, Travels; Second edition, p. 337.

chaux than many of his discoveries of new plants, and the provisional name may well have escaped his memory in the midst of the perils and fatigues of his arduous life.

There is certainly no evidence in this Journal that Michaux had ever seen the *Magnolia cordata* of his flora at the time this winter journey to the Blue Ridge was undertaken. No mention is made of the discovery of such a plant during his journey from the coast to the head waters of the Tennessee in the summer of 1787, when it is probable his first visit to the southern mountains was made. Michaux had landed in America as early as November of 1785 The first part of his journal is lost, however, and it is impossible of course to speak with any certainty of his movements during the first eighteen months of his stay in the United States. He had become perfectly familiar, however, as is shown by his journal, with the northern trees prior to his southern mountain journey of 1787, and as under date of January 14, 1787, he speaks of seeing, for the first time in America, *M. acuminata*, one of the common and most conspicuous trees of the southern mountain forests, it appears probable that his early explorations were confined to the sea-board and to the northern States. If this conclusion is correct, it would prove that Michaux was not in pursuit of *M. cordata*, for he would hardly have gone to the mountains in December to search for a tree the existence of which even was unknown to him. On the other hand, had he previously discovered his *M. cordata* and become familiar with its appearance, he would not have undertaken, keen observer as he was, to distinguish it in winter without foliage from *M. acuminata*, one of the common trees of the region, although he would have had no difficulty at any season of the year in distinguishing the bark and bud scales of *M. auriculata*, the tree it must appear evident he was in pursuit of.

It has been suggested that the spot described by Michaux as the "Tête du Keivi" might have been the junction of two rapid mountain torrents, the White Water and the Devil's Fork, which drain the eastern slope of the mountains between the Tugalo and the Keowee, unite, and then join the Keowee. It is more probable however, that the spot described as the head of the Keowee is the junction of the Toxaway and Horse Pasture Rivers, several miles above the mouth of the White Water and close to the North Carolina boundary, although within the limits of the State of South Carolina. They are swift rivers flowing through beds cut deep in the rock, broken by innumerable rapids, and full of logs and bowlders; in each about six miles from its mouth is a noble fall, or rather a series of cascades of great height and beauty. It was near one of these falls probably that Michaux wished to camp on the evening of the 9th of December, and the evidence favors the belief that it was the falls of the Toxaway. The principal Indian trail, leading from the low country to the Cherokee hunting ground on Hogback at the head of the Tuckasegee River, passes by the mouth of the Toxaway to the falls of that river, and then up through the deep ravine north of the Hogback Mountain separating it from Tigertail. Michaux, guided by his Cherokee and anxious to reach the highest mountain in the region, would naturally have followed the more beaten Toxaway trail which leads directly up Hogback, the highest mountain in this neighborhood, rather than by the Horse Pasture to Chimney Top and the less elevated mountains which surround Casher's Valley. He probably camped that night in the shelter of the deep ravine north of Tigertail, where he would have found no pine wood for the fire, and which to-day is covered with a dense forest of deciduous trees. On the 10th, had he ascended the mountains from this camping place, he might have reached the spot where the waters of the Savannah and Tennessee spring from the opposite sides of a narrow ridge. He would have found the mountain forests abounding with *Magnolia auriculata* and *M. acuminata*, and he would have been obliged to cross a great thicket of *Rhododendrons*, the only one, it is said, three miles wide in all this part of the country. It is to-day the greatest bear ground in all the Carolina mountains, and according to tradition one of the most famous of the Cherokee hunting resorts. A chain of high mountains stretching from west to east may be seen from Hogback. It is now called the Balsam Range.

The distance from the summit of Hogback to the head of the Keowee is not more than fifteen miles by the Indian trail. Michaux might therefore have made the ascent from his camp under Tigertail, gathered his Magnolia, and returned to the junction of the two rivers on the evening of the second day. He could hardly have done it in less time at that season of the year, especially if he penetrated far into the Rhododendron thicket.

A little plain less than a hundred acres in extent, now converted into a corn field and dotted with the homes of a few poor families, marks the junction of the Toxaway and the Horse Pasture. The mountains which are "exposées au sud," that is, which face the left bank of the Keowee below the junction of its two mountain branches, are still covered with *M. auriculata*. From the opposite shore at the foot of the mountains which face the north, fifty paces below the junction, the Cherokee hunting trail, as smooth and hard to-day under the tireless steps of the moon-shiners as it was ninety-eight years ago when Michaux saw it, leaves the river, crosses the little brook and stretches up to the mountains; and here with *Epigea repens* may still be found Michaux's little "*arbuste*" with its "*feuilles denticulées*," the *Shortia* of Torrey and Gray.*

There is no mention in Michaux's Journal of his discovery of the *Magnolia cordata* of his Flora, and no satisfactory record exists that any American botanist has ever collected in a wild state this plant as it is known in cultivation. The younger Michaux in his Sylva says:—"the banks of the Savannah in upper Georgia and those of the stream which traverses the back parts of South Carolina are the place where my father and myself particularly observed this tree." A careful examination made by me on this region and extending over two years, has not resulted in the discovery of *M. cordata*, nor does this tree now grow on the Savannah River about Augusta, where the younger Michaux says that he found it also.

The *Magnolia cordata*, as known in gardens, differs from *M. acuminata* in its thicker branchlets, its less pyramidal habit, and in its generally broader leaves, sometimes, though rarely, sub-cordate at the base, darker green above and more densely pubescent beneath. These appear earlier in the spring and remain upon the trees somewhat later in the autumn. The flowers are often less than half the size of those of *M. acuminata* and are bright yellow instead of pale yellow or green in color. The two trees growing side by side in gardens certainly look distinct; but at different points in the Blue Ridge in North and South Carolina and Georgia and on the mountains of North Alabama, individual Magnolias grow with leaves and flowers intermediate in shape and color between those of *M. acuminata* and the *M. cordata* of gardens, which indicate the close connection between these two species. The specimens collected by Dr. Chas. Mohr in Winston County, Alabama, are nearly identical with the cultivated *M. cordata*, while other specimens

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* The botanical readers of this Journal are familiar with the interesting history of this plant. In 1839 Dr. Asa Gray found among the undescribed plants of the Michaux Herbarium in the Museum d'Histoire Naturelle in Paris, a single specimen, in fruit only, of a *Pyrola*-like plant collected in the high mountains of Carolina, and which he characterized as the type of the new genus which now commemorates the botanical labors of Dr. Chas. W. Short of Kentucky. A second species of *Shortia* discovered afterwards in Japan confirmed the characters and validity of the genus; but for many years all efforts to rediscover Michaux's plant, although diligently and widely sought by every botanical traveler in the Carolina mountains, failed. In May, 1877, however, *Shortia* was unexpectedly discovered near Marion, North Carolina, at a considerable distance from the high mountains, by G. M. Hyams; so that this second rediscovery is principally interesting in the light it throws upon the route taken by Michaux in his winter journey. There can be no reasonable doubt that *Shortia* was the "*Arbuste*" with "*f. denticulées*" of the Diary, although the term "*Arbuste*" is misleading. *Shortia* is not a shrub, of course, but an herb with stoloniferous stems. The plants gathered by Michaux "in great quantities" probably all perished before reaching France or could not be made to adapt themselves to cultivation. At any rate, there is nothing to indicate that such a plant was ever cultivated in the Paris garden.

from these intermediate forms can only be distinguished from the typical *M. acuminata* by their occasional sub-cordate leaves and smaller flowers. The facts, then, in the case are these. No botanist during the present century has ever discovered in a wild state a tree exactly like the *M. cordata* of gardens, which is now only known by trees propagated and possibly changed by cultivation from the plant or plants introduced into France by Michaux. Forms intermediate in character between *M. acuminata* and *M. cordata* are common in a wild state in the region often visited by Michaux, and where his son says that *M. cordata* was discovered by his father and himself. It is not improbable, therefore, that *M. cordata* may have been founded by Richard, the author of Michaux's Flora, on a specimen from one of these doubtful trees which Michaux himself had not distinguished in the field as a distinct species. But whatever may have been the origin of the species described in Michaux's Flora, these intermediate forms between the two species, which have been discovered of late years, seem to make it necessary to consider Michaux's *M. cordata*, as known in gardens, to be a rare and local variety of *M. acuminata*.*

[Since this article was placed in the printer's hands, Professor Sargent has received a letter from a correspondent resident in the region, reporting the discovery of the *Shortia* at another station in the vicinity, where there were "rods covered with it." We may now hope that the continued survival of this notable member of our flora is assured. The interest of botanists in this rediscovery of the original habitat by Professor Sargent, and its extension by his correspondent, is of the highest.

Let me add that "les sauvages" who told Michaux that the leaves are pleasant-tasted and aromatic when crushed, must have had reference to *Gaultheria procumbens* and not to the *Shortia*, the foliage of which is slightly mucilaginous and odorless.—A. GRAY.]

ART. LV.—*Note on the Age of the Swedish Paradoxides Beds;* by S. W. FORD.

IT has been customary to look upon the Swedish Paradoxides beds as representing, in part, the oldest known portion of the Primordial zone. M. Linnarsson, in comparing these beds with those of the Menevian and Harlech groups of Great Britain, states that the latter "correspond to the Swedish Paradoxides beds and, in part, to the sandstones underlying the Paradoxides

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* *Magnolia acuminata* var. *cordata.*

M. foliis lato-ovalis basi subcordatis vel ovalibus acuminatis subtus pubescentibus vel subtomentosis; floribus flavis.

A small tree sometimes 60 feet in height, the leaves darker green and more persistent than those of the species with which it is often associated on dry ridges and mountain slopes. Northern Alabama. (C. Mohr) Blue Ridge, North and South Carolina (Sargent) and common in gardens.

beds."* More recently Mr. G. F. Matthew, in announcing the interesting discovery of the Swedish species, *Paradoxides Kjerulfi* Linnarsson (*Olenellus* (?) *Kjerulfi* Brögger) in America,† states that this species, if "present in America at a horizon corresponding to that at which it occurs in Europe, should show itself in band *b* of Division 1" of the New Brunswick measures, instead of in strata which are regarded as the equivalents of the Menevian group of the British geologists; from which it would appear that he also considers the Swedish Paradoxides beds as in some measure equivalent to the Harlech or Solva formation. According to Mr. Matthew, *P. Kjerulfi* has been found both in Newfoundland and in the Kennebecasis Basin of New Brunswick; and is associated in the latter locality with a number of species found in the St. John Basin, which are similar to and in some cases identical with those of the Menevian group of Wales. The beds in which it occurs in Newfoundland, were set down as Menevian by Billings, so long ago as 1872.

The several subdivisions recognized in the Swedish Paradoxides beds, and their order of succession, were given by M. Linnarsson in 1876 as follows:

(6.) Strata with *Agnostus lævigatus.*
(5.) Strata with *Paradoxides Forchhammeri.*
(4.) Strata with *Paradoxides ölandicus.*
(3.) Strata with *Paradoxides Davidis.*
(2.) Strata with *Paradoxides Tessini.*
(1.) Strata with *Paradoxides Kjerulfi.*

With respect to the above succession, M. Linnarsson admits that the position of the fourth subdivision, or that of the "Strata with *Paradoxides ölandicus*," is doubtful. Division 2 holds, in addition to *Paradoxides Tessini*, the British species *P. Hicksi* Salter, which is followed in the next superior division, as in the Welsh measures, by the great *P. Davidis*. The position of *P. Hicksi* in the British beds is in the lower portion of the Menevian group, and that of *P. Davidis* in the middle; and this, it will be seen, is almost exactly their position in the Swedish Paradoxides beds. Salter has pointed out the fact that *P. Hicksi* is a good deal like an *Anopolenus.* The bulk of the Swedish fauna appears to be concentrated in Div. 5, or in that of the "Strata with *Paradoxides Forchhammeri*," which had yielded, up to 1876, about forty species, representing the genera *Paradoxides*, *Agraulos*, *Anomocare*, *Liostracus*, *Dolichometopus*, *Conocoryphe*, *Solenopleura*, *Elyx*, *Harpides ?*, *Aneuacanthus*,

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* "On the Brachiopoda of the Paradoxides beds of Sweden," p. 27, 1876. (Bihang till K. Svenska Vet. Akad. Handlingar. Band iii, No. 12).

† This Journal, III, xxxi, p. 472.

Corynexochus, *Agnostus*, *Hyolithes*, *Orthis*, *Lingulella*, *Obolus ?*, *Obolella ?*, *Acrotreta*, *Acrothele*, *Kutorgina* and *Iphidea*. Of these, two, *Orthis Hicksi* and *Obolella? sagittalis*, are well-known Welsh Menevian species. A considerable number of the genera of the Swedish measures are wanting in the British Menevian beds, and *vice versa;* but this, I think, is no more than might be reasonably expected in the case of so widely separated exposures of the same formation.

In view of the above facts, I think we may assume with a very considerable degree of confidence, that the Swedish Paradoxides beds, or at any rate those above the Division characterized by *Paradoxides Kjerulfi*, are of the age of the Menevian group; and the question arises whether there is anything in the aspect or structure of this species to prevent the division in which it occurs from being also regarded as Menevian. In an earlier paper (this Journal for October, 1881), I have discussed at some length the structure and relations of this species; and I see no good reason at present to modify the opinions concerning its affinities therein expressed. The view I took at that time was, that *P. Kjerulfi*, although confessedly an aberrant form, should nevertheless be regarded as a *Paradoxides*. There are a number of strong points of resemblance between this species and *P. ölandicus* Sjögren,* judging from the figures which I have seen of these forms; and that the latter is a true *Paradoxides* I think admits of no question. The Swedish *Paradoxides*, like those of the typical Menevian beds, and unlike those of Bohemia, are all, so far as determined, of the *Brachypleural* type; i. e., have all of their anterior pleura of the same relative length in the fully developed or adult forms; but whether this is true of the particular species *P. Kjerulfi* is not at present known. I have elsewhere presented reasons for believing that the *Brachypleural* species of the genus *Paradoxides* are more recent than the *Macropleural*, based upon facts furnished by the Life History of *Olenellus asaphoides*. Mr. Matthew, in speaking of the American specimens of *P. Kjerulfi*, says that the glabella is not enlarged in front as in the true *Paradoxides;* but the figures given by M. Linnarsson show that in the Swedish specimens, or at any rate, in those illustrated, it is. He further says that the position of this species (which he calls, upon the authority of Professor Brögger, *Olenellus* (?) *Kjerulfi*) in Europe, "is beneath that of the beds carrying *Paradoxides;*" but until it is proved that *P. Kjerulfi* is not a *Paradoxides*, it seems the better course to say this its position in Europe is at the *base* of the Swedish beds carrying *Paradoxides.*

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* Geol. Fören. Förhandl., Bd. i, p. 72, t. 5, fig. 1, 1872.

In any event, the facts (1) that the position of *P. Kjerulfi* in the Swedish Primordial is directly below the zone carrying the British *P. Hicksi;* (2) that it is clearly allied to *P. ölandicus,*—a *Brachypleural* species and an undoubted *Paradoxides;* and, (3) that it is a Menevian species in America; all appear to me to indicate that it is a Menevian species in Europe also, and that the strata there affording it may be regarded as constituting a legitimate portion of the Swedish *Paradoxides* measures.

Schodack Landing, N. Y., Sept. 25th, 1886.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of Fusing points.*—**Roth** has suggested a new form of apparatus for determining fusing points. It consists of a bulb 65^{mm} in diameter, having a neck 200^{mm} long and 28^{mm} wide, within which is a straight tube closed at bottom, 15^{mm} wide, sealed to the outer tube above and passing down to within 17^{mm} of the bottom of the bulb. The outer tube has a lateral tubulure closed by a perforated stopper, so that communication with the outer air may be opened or cut off at will. The flask is filled to two-thirds its height with sulphuric acid. To use the apparatus the substance is placed in the inner tube and the temperature of the acid is gradually raised until fusion takes place, the temperature being carefully noted by an accurate thermometer placed within this inner tube. A comparison by the author shows that the correction required when the thermometer is placed in the sulphuric acid, brings the corrected fusing point to the value directly observed by the method now described, within the limits of the errors of observation. Thus the fusing point of benzoic acid with the thermometer in the acid, is 121·5°, and corrected 123·3°; while the temperature observed directly in the inner tube was 123°. Nicotinic acid fused at 228°, or corrected at 234·6°; while the temperature observed in the tube was 235°.—*Ber. Berl. Chem. Ges.*, xix, 1970–1973, July, 1886.

G. F. B.

2. *On the Determination of Molecular Weights of Substances by means of the Freezing points of their Solutions.*—In order to ascertain how far the method proposed by Raoult for fixing molecular weights by means of the depression of the freezing point,* was applicable to organic compounds, **Paterno** and **Nasini** have submitted to examination (*a*) several pairs of polymers, such as aldehyde and paraldehyde, acetonitrile and cyanmethin, cyanamide and dicyanamide etc.; and (*b*) certain bodies whose molecular weight is not as yet fixed, such as lapachoic acid and lapachon,

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* See this Journal, xxix, 399, May, 1885.

picrotoxine and picrotoxide hydrate, santonin and santonid. Raoult's method was strictly followed. The quotient of the depression of the freezing point in degrees by the concentration of the solution, i. e., the weight of substance in 100 c.c. of it, gives the depression coefficient, or the depression given by one gram of the substance in 100 c.c. This, multiplied by the molecular weight, gives the molecular depression. Thus, for aldehyde C_2H_4O in water the depression-coefficient for various strengths of solution, was 0·4107, 0·4274, 0·4279 and 0·4369; the corresponding molecular depressions being 18·07, 18·81, 18·83 and 19·22. For paraldehyde $(C_2H_4O)_3$, the depression-coefficient was 0·1458, 0·1513, and the molecular depression 19·24 and 19·97; practically the same. Cyanamide CN_2H_2 has a molecular depression of 16·28, dicyanamide $(CN_2H_2)_2$ of 15·54. Acetonitrile $CH_3 . CN$ afforded a molecular depression of 17·78, 17·28, and 18·61 in three experiments; but cyanmethin $(CH_3 . CN)_3$ varied its depression-coefficient from 0·0786 to 0·0461 according to the concentration of the solution; giving a molecular depression varying from 5·67 to 9·67. This would suggest a molecule two or three times as large, either $(CH_3 . CN)_6$ or $(CH_3 . CN)_9$; values not in accordance with the vapor density or chemical behavior of this substance. Lapachoic acid $C_{15}H_{14}O_3$ in benzene gave a molecular depression of 46·37; and lapachon, with the same formula, one of 43·10. Picrotoxine $C_{12}H_{14}O_5$, in acetic acid, gave 43·15, and 43·22; while picrotoxide hydrate $C_{15}H_{18}O_7$ gave 44·98 and 40·98 in two experiments. In general the authors consider Raoult's law to be exact, and regard it of great value in fixing molecular weights. Their experiments are to be continued. —*Ber. Berl. Chem. Ges.*, xix, 2527–2530, Oct. 1886. G. F. B.

3. *On the Magnetic Rotation of mixtures of the Fatty Acids, of Alcohol and of Sulphuric Acid, with Water.*—PERKIN has continued his researches upon the relation between the chemical constitution of substances and their power of rotating the plane of polarization when under magnetic influence,* and has now given the results of his examination of the rotation produced in mixtures of water with the fatty acids, with alcohol and with sulphuric acid. He calls the specific rotation of a substance the ratio of its observed rotation to that of water under the same conditions. By multiplying the specific rotation thus obtained by the ratio of the molecular weights of the substance and of water, and then dividing by the density of the substance, the molecular rotation of the given substance is ascertained. In a previous memoir, he had shown that the molecular rotation of water, assumed as unity, is not the same as the sum of the values of oxygen and two of hydrogen as deduced from the molecular rotation of other compounds. Thus hydrogen is found to be 0·254, while oxygen in hydroxyl varies from 0·194 in ordinary alcohols to 0·137 in monobasic acids, and is 0·261 in carbonyl. Taking the lowest numbers, $H_2+O=0·645$, and the highest, it is 0·769, instead of one. This difference between the molecular

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* See J. Chem. Soc., xlv, 421–580, Sept., 1884.

rotation of water in the free and in the combined form suggested the possibility of determining by means of the magnetic rotation whether the water in hydrated compounds existed as such or whether it was present in actual combination. If the former, the numbers obtained should represent the value for the compound plus that of the water; if the latter, lower values would be obtained. Thus if a molecule of formic acid were mixed with a molecule of water we might have either $HCOOH+H_2O$, or $HC(HO)_3$; the molecular rotation being in the first case 2·671 and in the second not over 2·340. Experiment gave 2·666. The molecular rotation of acetic acid, under the same conditions, was 3·554, of propionic acid 4·512, and of ethyl alcohol, 3·787; the calculated values on the supposition that the water exists as such in them, being 3·525, 4·462 and 3·780 respectively. "The foregoing results," the author says, "are further evidence of the fact that although thermal changes and alterations of density result from chemical action, yet that they themselves are not evidence of chemical action." With sulphuric acid, whose molecular rotation was 2·315, it was found that the addition of one molecule of water brought this value to 3·188, two molecules to 4·113, and three to 5·064; the calculated values of course being 3·315, 4·315 and 5·315. There is hence an increase of rotation in the first case of 0·873, in the second of 0·925 and in the third of 0·951. These numbers indicate that the largest amount of combination takes place when the first molecule is added and therefore it seems probable that only one chemical compound results from the action of water on sulphuric acid, namely, $(HO)_4SO$. With regard to water of crystallization, the author calls attention to the want of consistency as to the presence or absence of such water in the simple salts of metals belonging to the same class; such for example as the salts of silver, potassium and sodium. These inconsistencies are so great that it is impossible in his opinion to believe that water of crystallization has any relationship to chemical combination. It appears to him that the relationship is a purely physical one, its presence with the compound being necessary for the building up of the crystalline form which can most readily be produced. "If a salt by itself," he says, "can produce the most easily formed crystalline structure, it will naturally do so and be anhydrous; but if on the other hand it cannot do so, it will associate itself with that number of molecules of water with which it can most readily produce the crystalline form."—*J. Chem. Soc.*, xlix, 777–790, October, 1886. G. F. B.

4. *On the Behavior of Alkali-earths and their Hydrates to dry Carbon dioxide.*—Scheibler has undertaken a series of experiments in order to ascertain the action which dry carbon dioxide exerts upon the alkali-earths and their hydrates. The following are his conclusions: 1st. Perfectly dry carbon dioxide does not combine either with the caustic anhydrous oxides of the earth-metals or with their mono-hydrates; or with hydrated ba-

rium monohydrate, $Ba(OH)_2+1$ aq. 2d. When the hydrates $Ca(OH)_2$, $Sr(OH)_2$ and $Ba(OH)_2+1$ aq. contain more water than corresponds to these formulas, this excess of water is set free at temperatures above 100° C. solely by the action of the heat, and is then carried away by the current of carbon dioxide gas precisely as it would be in a similar current of an indifferent gas. But now the carbon dioxide becomes by this means moist and reacts upon the monohydrate to form carbonate, the amount of which is proportional to the quantity of water set free. Complete conversion of the hydrate into carbonate does not take place even when the water set free reaches its maximum, as in the case of the crystallized hydrate $Sr(OH)_2+8$ aq. 3d. The use of a current of dry carbon dioxide for the purpose of driving out by the aid of heat the combined water of the alkali-earths and the conversion of these earths completely into carbonates, is not satisfactory as an analytical method.—*Ber. Berl. Chem. Ges.*, xix, 1973–1982, July, 1886. G. F. B.

5. *On the Synthesis of active Conine.*—LADENBURG has repeated his experiments upon the synthesis of conine upon a larger scale and has confirmed his former results. The α-allylpyridine was prepared by heating the carefully purified α-picoline in sealed tubes with paraldehyde to 250°–260° for ten hours. From 1 kilo crude α-picoline, by repeating the process, 380 grams pure α-picoline and 45 grams allylpyridine were obtained. Its reduction to α-propylpiperidine was effected by means of sodium, and yielded nearly the theoretical quantity. The hydrochlorate crystallized in white silky needles permanent in the air and fusing at 203°–205. The base itself shows the closest similarity to conine, agreeing with it in odor and in its behavior to water, in its specific gravity, 0·8626 at 0°, and in the properties of its salts, especially the double chlorides of gold and of platinum. To still further establish the identity of these bodies, the author converted the α-propylpiperidine into conyrine and observed identically the same fluorescence in the crude product though the pure substance was free from it. The platinum salt had the same fusing point and the same crystalline form. The physiological action of α-propylpiperidine is identical with that of conine as proved by Falck. The author believes that he has established the complete identity of these two substances, and therefore has prepared for the first time by pure synthesis a vegetable alkaloid.—*Ber. Berl. Chem. Ges.*, xix, 2578-2583, October, 1886. G. F. B.

6. *On the Identity of Cadaverine with Pentamethylenediamine.*—LADENBURG has succeeded in identifying the base which Brieger discovered a year or more ago in the dead body and which he called cadaverine, with the base recently discovered by himself and called pentamethylenediamine. The two bases have the same boiling point, the same solubility and the same odor. The mercury double salt, however, obtained from pentamethylenediamine hydrochlorate by mixing its solution with one of mercuric chloride, forms crystals having the formula $C_5H_{14}N_2(HCl)_2$

$(HgCl_2)_3$; while the cadaverine salt seems to have four mercuric chloride molecules. Moreover the author has converted cadaverine into piperidine and observed its identity with that from the other base. Its chlorhydrate fused at 237°, and it formed a beautifully crystallized double platinum salt fusing at 194°–195°. —*Ber. Berl. Chem. Ges.*, xix, 2584–2586, October, 1886. G. F. B.

7. *On a method of obtaining Hydrochloric acid absolutely free from Arsenic.*—The large quantity of hydrochloric acid which is required to destroy the organic matter by the process of Fresenius and Babo in cases of poisoning, renders it necessary to purify this acid from arsenic with the greatest care. OTTO, after giving the various methods proposed for doing this, calls attention to one which he has recently adopted. It was suggested by observing that the crude acid of commerce, after treatment with hydrogen sulphide and fractional distillation, contained not a trace of arsenic. Hence it appeared that the impurities present in the crude acid enabled the hydrogen sulphide to precipitate the arsenic completely. Experiment confirmed this conjecture and proved that the last minute trace of arsenic present in the purest hydrochloric acid of commerce is precipitated as arsenous sulphide in the presence of other impurities; and further that by adding to the acid before precipitation some substance precipitable by hydrogen sulphide, this last trace of arsenic can be absolutely removed. To test this question thoroughly, seven portions of hydrochloric acid, of two liters each, of sp. gr. 1·12 (one portion of which had been shown by Marsh's test to give a mirror corresponding to about one-tenth of a milligram of arsenous oxide, were treated as follows: (*a*) with 5 grams of a ten-per cent solution of ferric chloride, (*b*) with 2 grams of potassium dichromate, (*c*) with 2 grams mercuric chloride, (*d*) with 1 gram cadmium sulphate, (*e*) with 1 gram copper sulphate, (*f*) with 30 grams of a saturated solution of sulphurous acid, and (*g*) with 30 grams of a half-per cent solution of chlorine. These portions of acid were then saturated with hydrogen sulphide, and allowed to stand for some time. They were then filtered and the filtrate tested for arsenic without giving the slightest trace of a mirror. The precipitates from portions *a*, *b*, *f*, and *g* showed the presence of arsenic. Indeed even the presence of arsenous oxide itself determines the absolute precipitation of traces of arsenic from the acid. Two liters of the same acid as above were treated with 0·2 gram As_2O_3 and then with hydrogen sulphide. The filtrate was free from arsenic. To obtain pure hydrochloric acid the author advises that the crude acid of commerce be diluted to the sp. gr. of 1·12, treated with washed hydrogen sulphide to saturation, allowed to stand for 24 hours at 30°–40°, again treated with H_2S, and allowed to stand, the clear liquid decanted and carefully distilled, reserving the middle portions. In five liters of acid thus purified the author could detect no trace of arsenic by Marsh's test.—*Ber. Berl. Chem. Ges.*, xix, 1903–1919, July, 1886. G. F. B.

8. *Fluorescence.*—M. Lecoq de Boisbaudran calls attention to the fluorescence manifested by various salts of manganese under the influence of electrical discharges in vacuum tubes. The fluorescence of certain of these compounds provides an extraordinary sensitive reaction to detect the presence of manganese in substances which give no trace of it by ordinary reactions. Sulphate of lime and carbonate of lime mixed with very small proportions of manganese render, after strong calcination, magnificent fluorescence.—*Comptes Rendus*, No. 10, Sept. 6, 1886. J. T.

9. *Instantaneous Photography.*—M Marey has devised an arrangement by means of which the light coming from the background against which the quickly moving objects are photographed can be cut off. This light has hitherto affected the sensitive plates and often injured the clearness of the impression. By means of certain precautions, M. Marey has been able to reduce the time of pose, for each image, to ·002 of a second and hopes to still further reduce it. The new photographs show an extraordinary clearness of impression under the shortening of the time of exposure. The pivoting of the wings of birds upon their longitudinal axis is clearly shown and also other and various peculiarities of their flight. The author expresses his obligation to certain suggestions of Chevreul.—*Comptes Rendus*, No. 13, Sept. 27, 1886. J. T.

10. *A Potential strengthener for measurements.*—All electrometers hitherto constructed do not equal galvanometers in sensitiveness and accuracy of indication. Hallwachs has invented a species of induction machine which can be used in connection with a quadrant electrometer. His paper gives a careful description of the apparatus and a discussion of the errors to which it is subject. This apparatus consists of a half cylinder condenser, of which the collector can be set in rotation and thus be placed opposite, and in turn removed from the condensed plate. The instrument gives for one Daniell cell with a scale distance of 3 meters 300 scale divisions on changing the quadrants of the electrometer.—*Ann. der Physik und Chemie*, No. 10, 1886, pp. 300–313. J. T.

11. *Compressibility and Surface Tension of Liquids.*—W. C. Röntgen and J. Schneider are occupied upon a research in this subject with various chemically well defined substances. Their present paper is a preliminary one. Among its results, however, is the following: If the fluids examined are arranged in the order of compressibility, the following order is observed: J, No_3, Br, Cl, OH, SO_4, CO_3, H, Am, Li, K, Na. The authors discuss the order of compressibility of various salts of the above, for instance, $LiNO_3$, $NaNO_3$, etc., and find that the compressibility of a salt solution is smaller than the arithmetic mean of the compressibility of an equally concentrated solution of salt and of base.—*Ann. der Physik und Chemie*, No. 10, 1886, pp. 165–213. J. T.

12. *Observations on pure Ice and Snow.*—Some experiments have been made by T. Andrews in regard to the relative conduc-

tivity of ice and snow, the dilatation of pure ice, and its relative penetrability at various temperatures. In experimenting in regard to the first point a mass of water about 2 feet square and 1 foot high was converted into ice by a freezing mixture and a uniform temperature of 0° F. obtained. In place of the freezing mixture fresh snow was then supplied and the gradual increase of temperture noted by a series of thermometers until the whole mass was at 32° F. This required 73½ hours. The experiment was then repeated with pure snow lightly pressed together; 165½ hours were required to bring it up from 0° F. to 32° F. The relative conductivities obtained are expressed in a diagram, the conclusion being that the conductivity of the ice was about 122 per cent greater than the snow under the conditions of the experiment.

The dilatation of ice was measured between −35° F. and +32° F. The linear coefficients obtained are as follows:

Linear coefficient for 1° between +16° F. and +32° F.=0·000040876.
“ “ “ 0 “ +16 “ =0·000028042.
“ “ “ −21 “ 0 “ =0·000020484.
“ “ “ −30 “ −21 “ =0·000019744.

The hardness of ice at different temperatures between −35° F. and +32° F. was measured by the relative depths to which a blunt-pointed steel rod with a weight of 181½ lbs. on its top penetrated. It was found that between −35° F. and +10° or 20° F. the ice was nearly impenetrable, the depth of penetration being only ¼ inch at 10° and ⅔ inch at 20°; after which the power of resistance decreased rapidly with the temperature.—*Proc. Roy. Soc.*, xl, 544, 1886.

II. GEOLOGY AND NATURAL HISTORY.

1. *On the gaseous constituents of Meteorites.*—ANSDELL and DEWAR have continued the work begun by Graham and carried further by Mallet, Wright and others in regard to the gases occluded in meteorites. The results of the analyses of the gases in three meteorites are given in the following table, with which those obtained from a piece of fresh pumice are compared:

		Occluded gases in vols.	Percentage composition.				
	Sp. gr.	of the meteorite.	CO_2	CO	H	CH_4	N
Dhurmsala	3·175	2·51	63·15	1·31	28·48	3·9	1·31
Pultusk	3·718	3·54	66·12	5·40	18·14	7·65	2·69
Möcs	3·67	1·94	64·50	3·90	22·94	4·41	3·67
Pumice-stone,	2·50	0·55	39·50	18·50	25·4	---	16·60

In order to test directly the absorptive power of one of the porous stony meteorites, a sample of the powdered Dhurmsala stone, from which the gases had been already removed, was left in moist air under a bell glass for a longer or shorter period. The results are given for the different periods in the following table; the gases were drawn off at a low red heat after the time given in each case:

	Occluded gas in vols. of the meteorite.	CO_2	CO	H	N
After 24 hours	0·61	54·0	--	42·4	3·6
After 6 days more	2·47	47·0	5·0	47·0	1·0
After 8 days more	0·63	96·1	2·0	1·5	--

A nodule of graphite from the Toluca iron was next examined, and for comparison several terrestrial graphites and one artificial specimen (obtained from the action of oxidizing agents on the cyanogen compounds present in crude caustic soda) were tested in the same manner. A specimen of semi-decomposed gneiss from Canada containing disseminated graphite, and one of feldspar were also taken. The results were as follows:

	Sp. gr.	Occluded gases in vols. of the graphite.	CO_2	CO	H	CH_4	N
Celestial graphite,	2·26	7·25	91·81	----	2·50	5·40	0·1
Borrowdale "	2·86	2·60	36·40	7·77	22·2	26·11	6·66
Siberian "	2·05	2·55	57·41	6·16	10·25	20·83	4·16
Ceylon "	2·25	0·22	66·60	14·80	7·40	3·70	4·50
Unknown "	1·64	7·26	50·79	3·16	2·50	39·53	3·49
Artificial "	---	53·13	45·42	39·88	8·31	4·43	2·00
Gneiss	2·45	5·32	82·38	2·38	13·61	0·47	1·20
Feldspar	2·59	1·27	94·72	0·81	2·21	0·61	1·40

An examination was also made of the carbonaceous Orgueil meteorite with the following results:

	Sp. gr.	Occluded gases in vols. of the meteorite.	Percentage composition.				
			CO_2	CO	CH_4	N	SO_2
Orgueil meteorite	2·567	57·87	12·77	1·96	1·50	0·56	83·00

Deducting the sulphur dioxide which has been formed from the decomposition of the sulphate of iron, the meteorite is found to yield 9·8 times its volume of gas having the composition:

CO_2	CO	CH_4	N
76·05	11·67	8·93	3·33

The organic matter, which is the feature of the meteorite, contains according to Clöez: C 63·45, H 5·98, O 30·57, or corresponding nearly to the composition of terrestrial humus.—*Proc. Roy. Soc.*, xl, 549.

2. *Recent discovery of Emeralds and Hiddenite in North Carolina;* by W. E. HIDDEN (communicated).—On the second and ninth of last August, two crystal pockets were uncovered at the Emerald and Hiddenite mine in Sharpe's township, Alexander County, North Carolina, that yielded a few very remarkable crystals of emerald and of hiddenite. The emerald pocket extended in a nearly vertical direction for twenty feet and was about one foot in diameter and four feet in its extreme lateral extent. The associated minerals were quartz crystals (from one ounce to twenty pounds weight and some that were fluid-bearing), green muscovite (fuchsite?), rutile, dolomite and minute crystals of monazite. The emeralds found were nine in number and as

regards color, perfection of form, and crystallographic interest, have not been surpassed at this locality. The largest emerald weighed nearly nine ounces and was three inches long by one and three-quarters in diameter. All the crystals possessed the same relative proportion of thickness to length (2 : 3), and were alike in being doubly terminated. The plane of attachment to the walls seemed to be relatively the same on all. Hair-like needles of some unidentified mineral penetrated the emerald crystals more or less; which feature pertains also to certain rare crystals of green spodumene from the same locality. The occurring planes were principally the ordinary prism I and the basal pinacoid O, though 2–2, 1 and other pyramids were noticed. The usual characteristic feature of vertical striation was hardly observable. The polish of the basal pinacoids was remarkably perfect, as was shown by two of the crystals being placed end to end supporting each other when held vertically. One of the crystals was especially remarkable from having implanted upon a prismatic face, a very brilliant crystal (2×10 mm.) of rutile, of perfect form, which seemed to be in exact parallel position axially with the emerald. A very low obtuse pyramid was finely developed (2×6 mm.) on two of the crystals and upon being measured with a reflective-goniometer by Mr. Edward S. Dana has been proved to be new to the species. Its symbol is $\frac{1}{6}$–2 ($1{\cdot}1{\cdot}\bar{2}{\cdot}12$.) Its angle on O is 4° 27′ to 4° 49′ measured, 4° 44½′ calculated, also $\frac{1}{6}\text{–}2 \wedge \frac{1}{6}\text{–}2$, adj. = 4° 24′ measured and 4° 44′ calc. This new plane lies in the zone i–2 : 2–2 : O. It was striated horizontally.

The discovery above described was followed a week later by the finding of hiddenite (emerald-spodumene) crystals of fine color and in one instance of unprecedented size. They were found only about three rods west of the point where the emeralds were found. About ten ounces of fine green crystals were found in the pocket, which was but four feet in extent, and otherwise a very narrow seam in the partly disintegrated gneissic rock. The accompanying minerals were the same as in the emerald pocket already described; no beryls or emeralds were found with the spodumene, as is the general rule at this locality. The largest crystal weighed ½ an ounce and was two and three-quarter inches long and three-sixteenths by nine-sixteenths of an inch through the clino- and ortho-axes. It is a twin, with a projecting edge at the termination. The color at the terminal *end*, for three-quarters of an inch, was a fine emerald-green, while the balance of the crystal was of a chrysolite green shade.

3. *Mineral Physiology and Physiography*, a second series of chemical and geological essays, with a general introduction, by T. Sterry Hunt. 710 pp. 8vo. Boston, 1886 (S. E. Cassino).—The essays here collected include Dr. Hunt's more recent contributions to science, namely, "Nature in Thought and Language," "The order of the Natural Sciences," papers on the atmosphere, celestial chemistry, the origin of crystalline rocks.

The decay of crystalline rocks, a "natural system in Mineralogy," history of Pre-Cambrian rocks; on Serpentines, and "the Taconic question in Geology."

4. *Index der Krystallformen der Mineralien*, von VICTOR GOLDSCHMIDT. Band I, Lieferung 2; pp. 289 to 601. Berlin, 1886. (Julius Springer).—The second part of Dr. Goldschmidt's great work—noticed on page 475 of the last volume—completes the first of the three proposed volumes. All the mineral species through E are included here. The whole work is a model of thoroughness and accuracy and in clearness of presentation and beauty of typographical work it leaves nothing to be desired. It is to be hoped that the author's labors will receive the support from mineralogists which they decidedly deserve.

5. BOTANICAL NOTES.—*Lamarck's Herbarium*, which has been for more than half a century the property of the late Professor Rœper and at Rostock—far out of the way—has now, it is stated, been bought for the Jardin des Plantes at Paris, where it will be much more accessible. Probably it is not large, nor at all complete in his types of the species of the earlier volumes of the Dictionary. But so far as it goes it will be more helpful now that it is in its proper place.

The extensive series of drawings and descriptions of Manilla plants, made in the seventeenth century by the Jesuit *Kamel* or *Camellus* (in honor of whom was the genus *Camellia* named), and which Ray refers to as in his possession, had utterly disappeared. From an account recently given by M Paque to the Royal Botanical Society of Belgium, it appears that this work exists, in fine condition, in the library of the Jesuit's College at Louvain; that it belonged to A. L. de Jussieu at his death, was bought by Count de Limminghe at the sale of Jussieu's library in 1858, and presented to the College where it is now preserved. There are 257 botanical plates, containing 556 figures.

Dr. Saint-Lager has issued a new bulletin on *Le Procès de la Nomenclature Botanique et Zoologique* (Paris, Baillière, pp. 54), in which his well known reformatory ideas are reiterated.

Phytobiological Observations, on the Forms of Seedlings and the causes to which they are due, is the subject of the address to the Linnean Society of its retiring President, Sir John Lubbock, at the anniversary meeting in May last, now published, with copius illustrations, as an article in the Journal of that Society, No. 147. It brings to view adaptations rather than causes, in the old fashioned sense of the latter word.

Hooker's *Icones Plantarum*, vol. xvi, part 2, has just been brought out under the auspices of the "Bentham Trustees." It comprises plates 1526 to 1550, inclusive; none of North American plants. But Professor Oliver figures a new chinese genus, *Plagiospermum*, which is thought to be allied to the exceptional genus *Glossopetalon.* The alliance is not obvious, and the new genus has rather a Rosaceous look. A. G.

6. *Absorption of coloring matters by the living protoplasm of vegetable cells.*—The following extract from a recent work on Vegetable Physiology expresses in a few words the generally accepted view relative to the action of dyes on vegetable cells. "It is impossible to stain living protoplasm: it is when protoplasm is dead that coloring matters can penetrate into it." The first part of this statement requires an important qualification.

Passing by certain well known facts relative to the transient tinging of animal protoplasm in certain cases, noted by Heidenhain, Brandt, and Dreser, attention is asked to the recent discovery by Pfefferin (Unters. aus dem botan. Inst. Tübingen, Band ii, iv). Professor Pfeffer shows that when living vegetable cells are placed in *very dilute* solutions of certain coal-tar coloring matters, the protoplasm becomes distinctly colored, and remains tinged for a time. The best results are obtained by placing roots with attached root-hairs, in half a liter of pure water to which is added one ten-thousandth of one per cent of almost any of the so-called methyl colors, such as "methyl-green," "methyl-violet," "methyl-orange:" and such colors as safranin, Bismarck-brown, and the like. Nigrosin, and eosin, and two or three others are not well adapted to the purpose. After a short time, especially if the specimen is shaken in the solution, the protoplasm will be found distinctly tinged. But a few colors, notably methylene-blue, do not color the protoplasm at all, but impart to the cell-sap an intense color. In this case, the dye has passed through the protoplasm without tinging it, into the cell-sap which receives it. G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Astronomical Journal.*—It is gratifying that Dr. B. A. Gould has again undertaken the publication of The Astronomical Journal which was discontinued in 1861. A real impulse was given to Astronomy in this country by the first six volumes of the Journal. We may hope for a like effect from the renewal of the publication at this time. The object of the Journal is now, as heretofore, the advancement rather than the diffusion of astronomical knowledge.

The first number of the seventh volume is dated at Boston, Nov. 2, 1886. The price is $5 for twenty-four numbers, which, for the present, may be sent directly to Dr. Gould at Cambridge. It is earnestly hoped that a liberal support will be given to the undertaking.

2. *National Academy of Sciences.*—List of the papers entered to be read before the Academy at the session in Boston, Nov. 9th and 11th, 1886.

S. P. LANGLEY: The Solar-Lunar Spectrum.

E. C. PICKERING: Draper Memorial Photographs.

C. H. F. PETERS: A Chart of the Stars in the group Præsepe.

C. H. F. PETERS: A Catalogue of Stars from positions in various Astronomical Periodicals.

O. T. SHERMAN: A Catalogue of Bright Lines observed in the atmosphere of β Lyræ.

W. L. Elkin: On the relative motions of the Pleiades group deduced from measurements made with the Königsberg and Yale College heliometers.

C. A. Young: Some observations with Pritchard's Wedge Photometer.

C. Abbe: The question of Barometer Exposure.

G. W. Hill: On the Construction of New Tables of Saturn.

T. Sterry Hunt: A Basis of Chemistry.

T. Sterry Hunt: Hardness and Chemical Indifference in Solids.

Alpheus Hyatt: Primitive Forms of Cephalopoda.

Alpheus Hyatt: A Case of Evolution in the Migration of Forms.

Alpheus Hyatt: Lituites of the Limestones of Phillipsburg, Canada.

F. W. Putnam: Archæological Explorations in the Little Miami Valley, Ohio, conducted by F. W. Putnam and C. L. Metz.

E. D. Cope: On Lemurine Reversion in Human Dentition.

E. D. Cope: On the Columella Auris of the Tailed Batrachia.

Edw'd S. Morse: Change in Mya since the Pliocene.

A. S. Packard: The Cave Fauna of North America, with Remarks on the Anatomy and Origin of Blind Forms.

R. Pumpelly: On the Relation of the Green Mountain Rocks to the Taconic.

W. M. Davis: The Mechanical Origin of the Triassic Monoclinal in the Connecticut Valley.

Alfred Russell Wallace: On Wind as a Seed-Carrier in relation to one of the most difficult problems in Geographical Distribution.

3. *Catalogue of the Collection of Minerals of A. Dohrmann.*—Messrs. S. H. and H. Chapman have issued a handsome catalogue of the Dohrmann collection of minerals which is to be sold in Philadelphia about the middle of December. The catalogue contains a description of about 1100 numbered specimens, the majority of them gold or silver. A number of artotype plates give fine representations of some of the more striking specimens.

OBITUARY.

Charles Whittlesey.—Col. Whittlesey, whose decease is announced on page 412 of this volume, was a graduate of the United States Military Academy at West Point in 1831. His work in Geology began soon after, and in 1837 he was appointed an assistant on the Geological Survey of Ohio, which was then under Mr. W. W. Mather, and given the direction of the topographical department. From 1847 to 1851 inclusive, he was connected with the Government Survey of Lake Superior and the upper Mississippi with reference to mines and minerals; and from 1858 to 1860 he was by request of Prof. James Hall associated with him on the Geological Survey of Wisconsin. In 1848, 1859 and 1864, he made explorations in the mineral regions of Minnesota, and published a report on the same in 1866. Mr. Whittlesey was the author of papers on the drift of Ohio, the terraces of Lake Erie, and various other subjects, and in one of them described a new coal plant of peculiar type, which afterward received (through Dr. Newberry) the generic name of Whittleseya. His latest contribution to this Journal was in the spring of 1885, on the Preglacial Channel of Eagle River. Two of his papers are among the publications of the Smithsonian Institution.

Col. Whittlesey returned to military life in 1861, and served as State Military Engineer for Ohio volunteers, and afterward as Colonel. He was born in Southington, Conn., and died in Cleveland, Ohio, which had long been his home.

INDEX TO VOLUME XXXII.*

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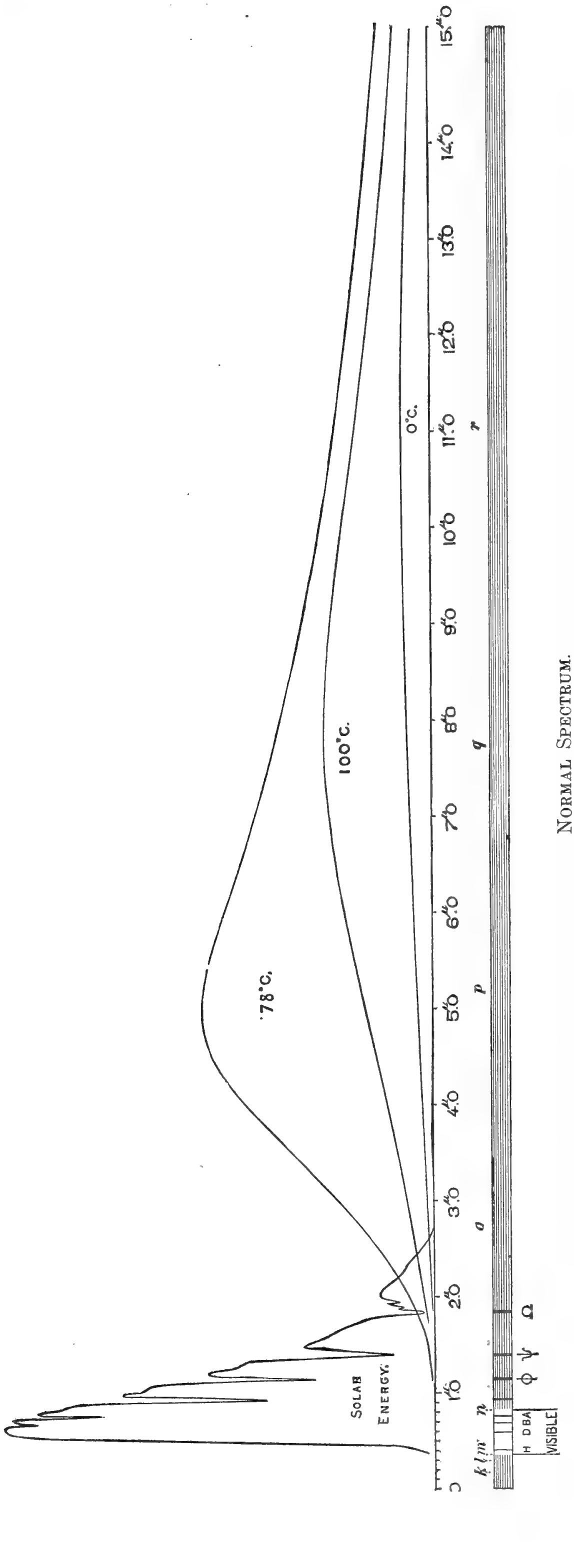
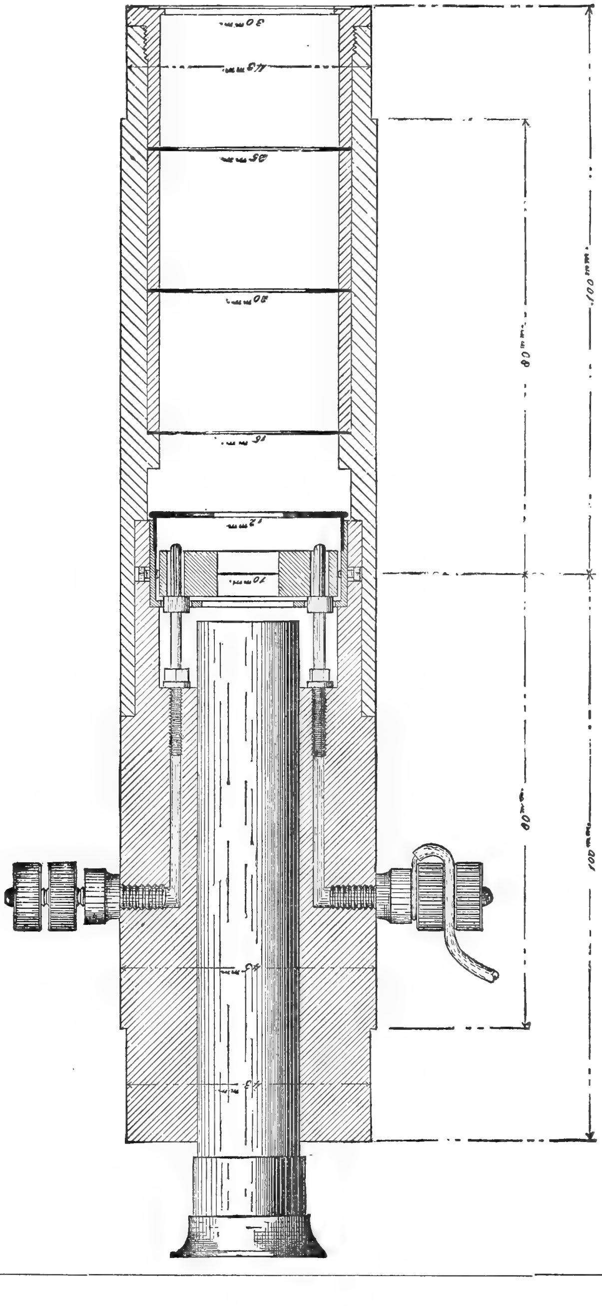
* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.



Normal Spectrum.



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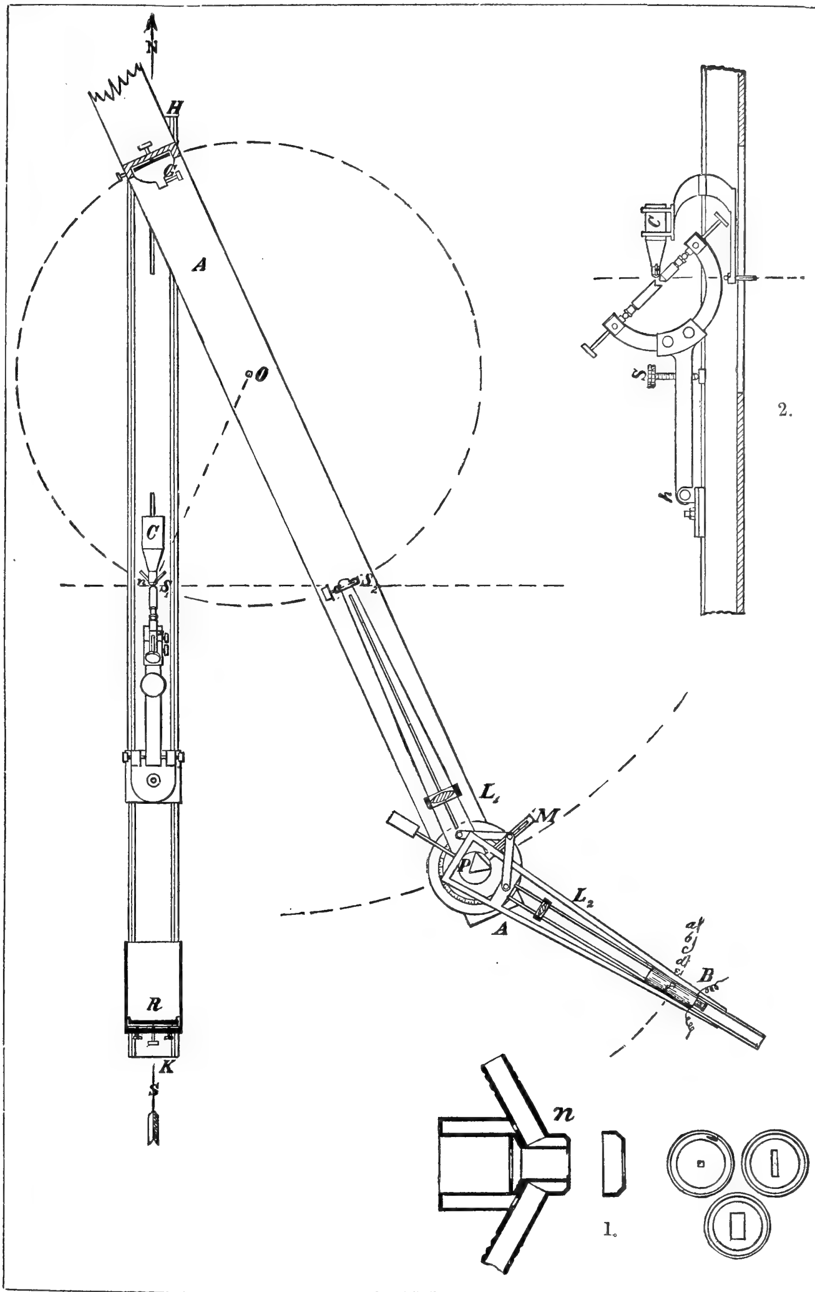
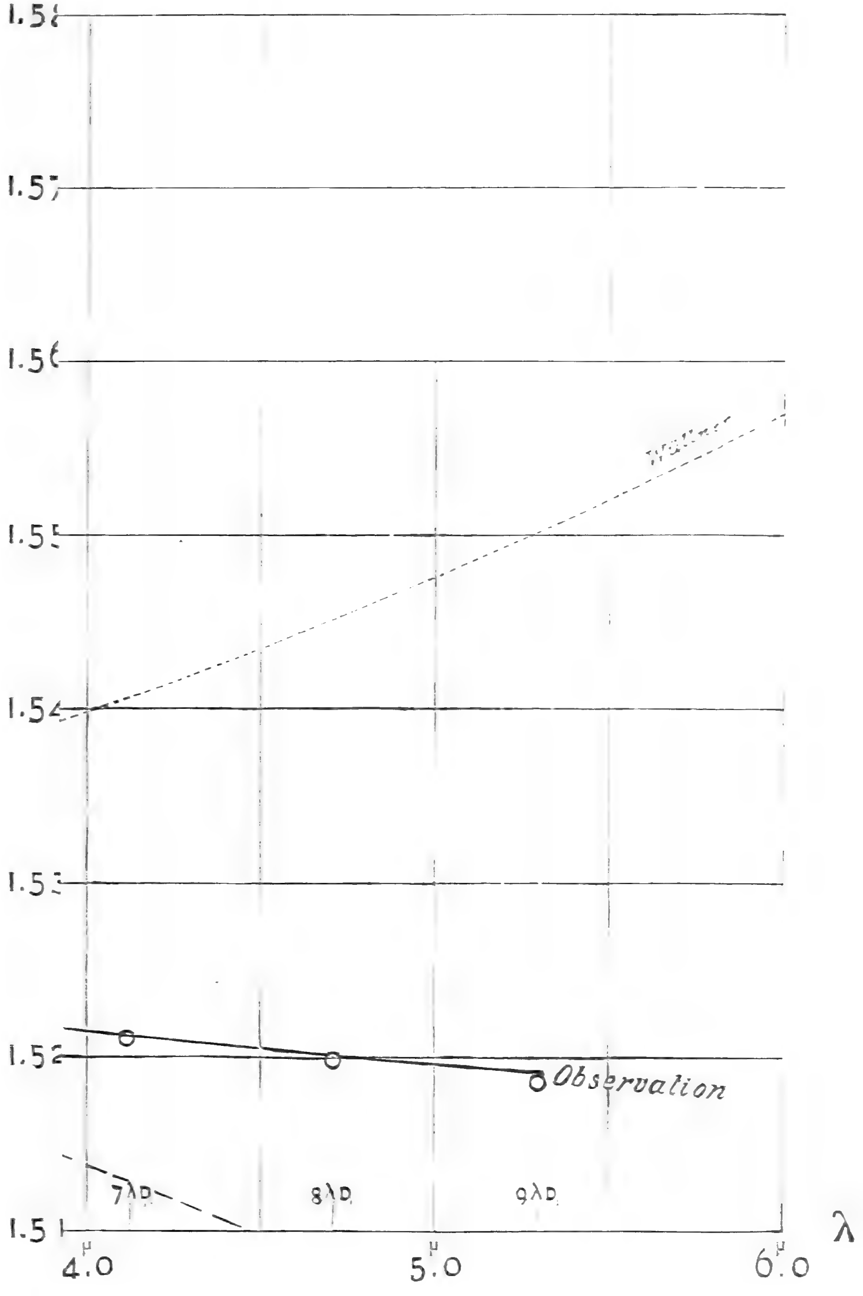


APPARATUS FOR DETERMINING THE RELATION BETWEEN INDEX OF REFRACTION AND WAVE-LENGTH.

Plate


1.58
1.57
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1.55
1.54
1.53
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Wüllner
Observation
7λD
8λD
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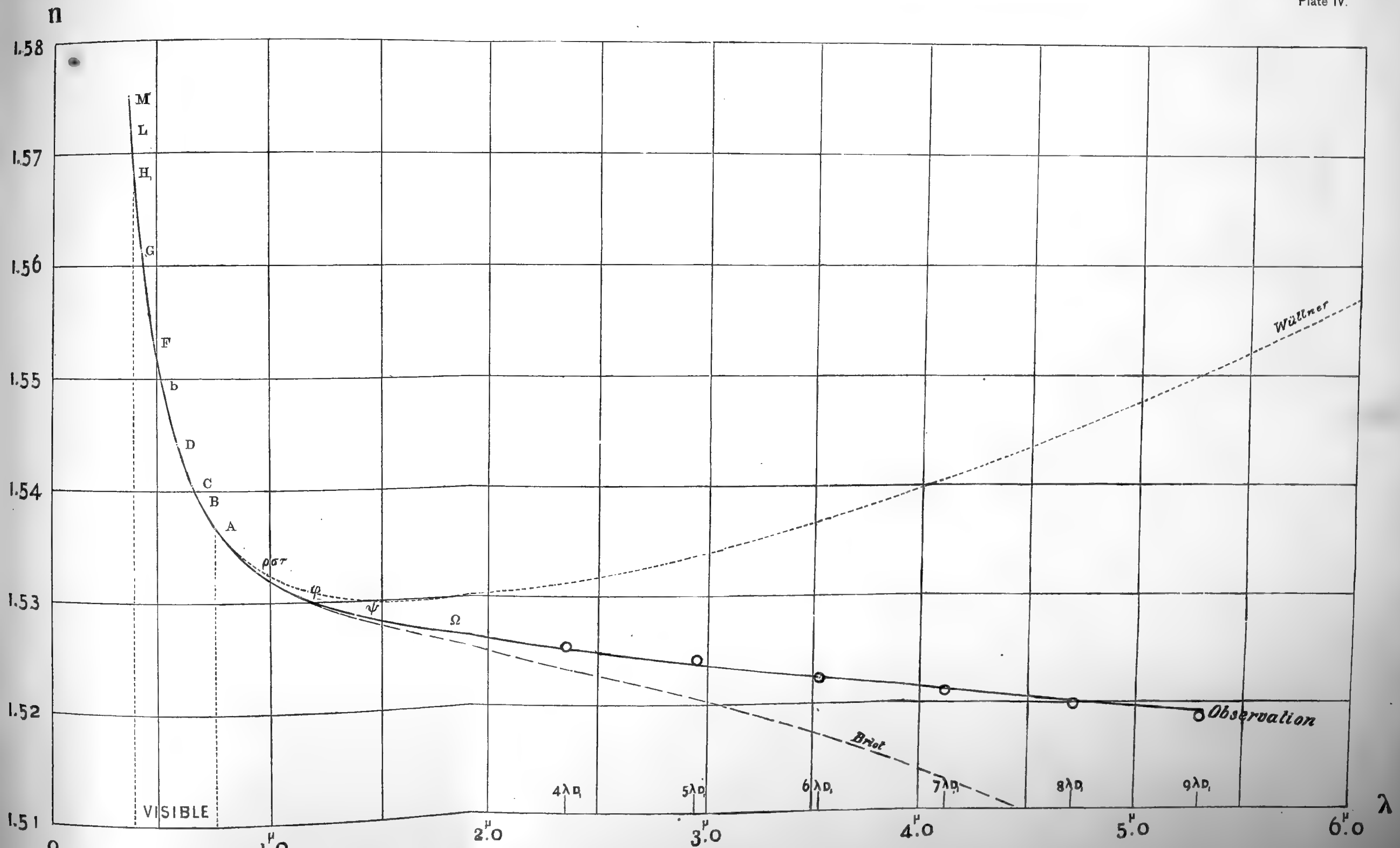
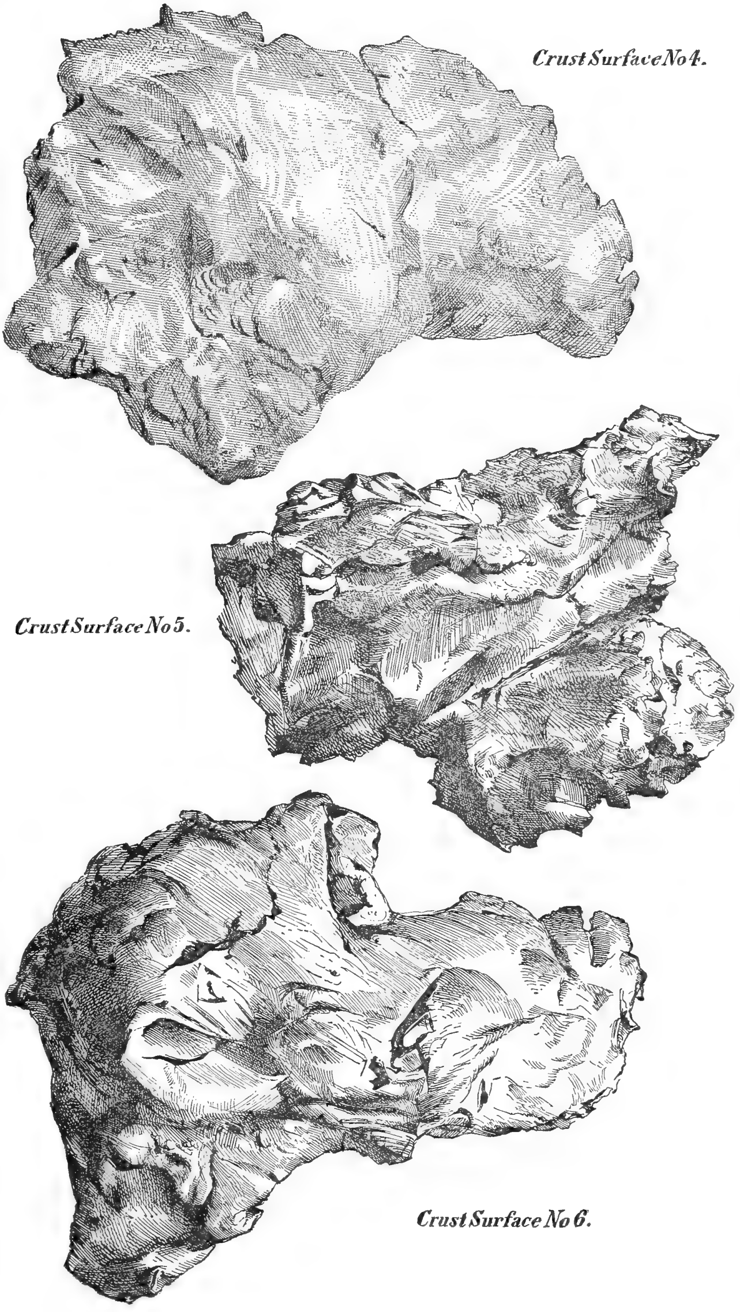
λ
4.0 μ
5.0 μ
6.0 μ



$n = \varphi(\lambda)$ FOR ROCK-SALT PRISM.

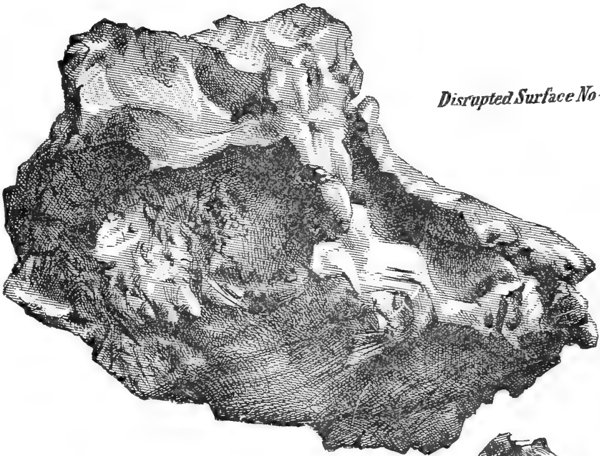


Crust Surface No 4.

Crust Surface No 5.

Crust Surface No 6.

GLORIETA METEORIC IRON.



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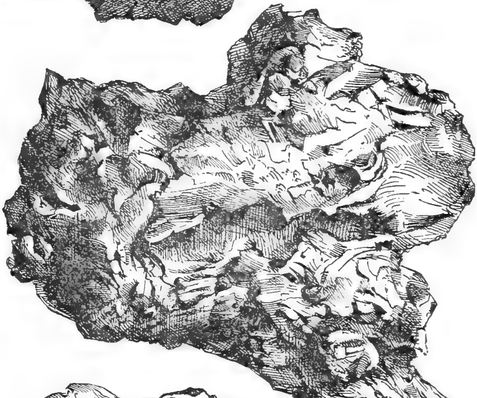

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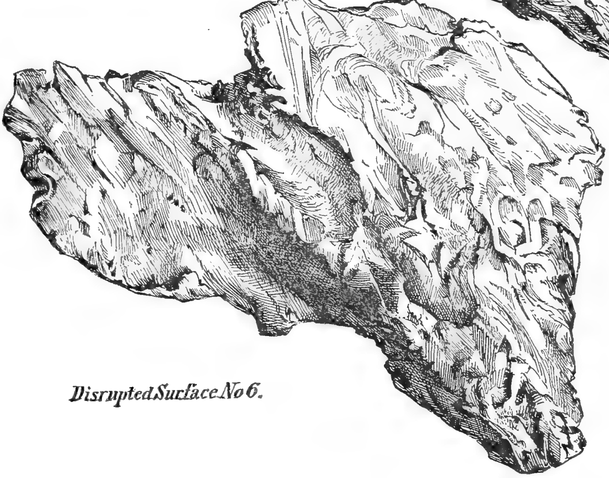

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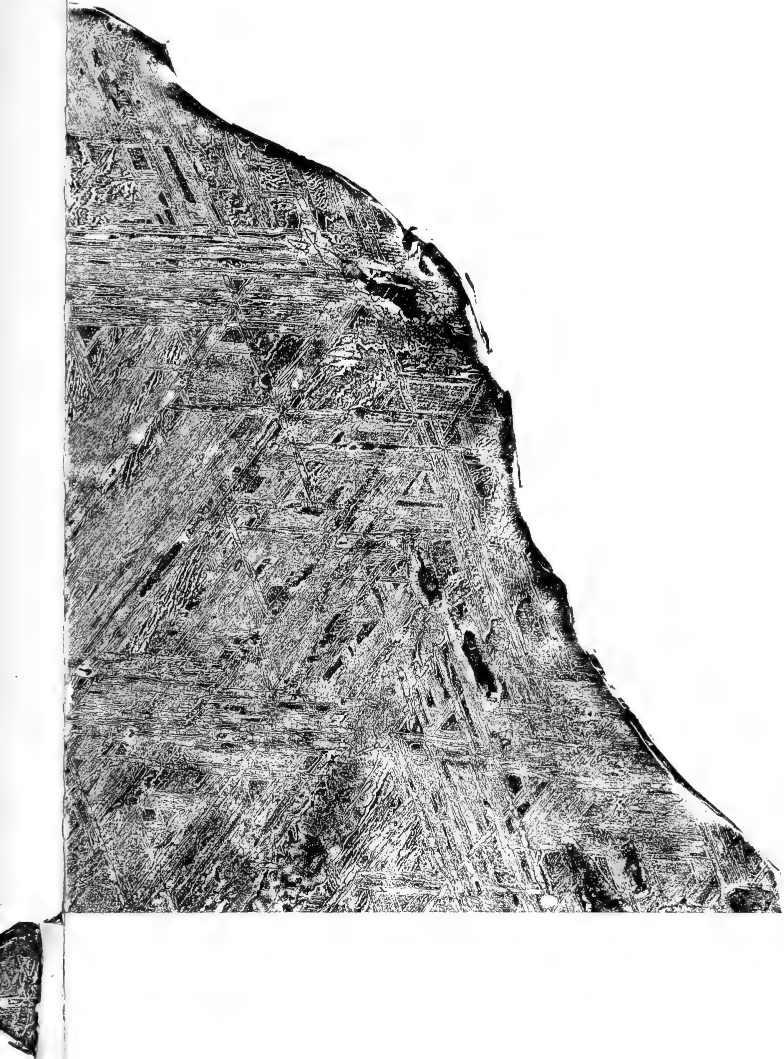
Glorieta Meteoric Iron.



LARGEST SECTION OF MASS No. 1.

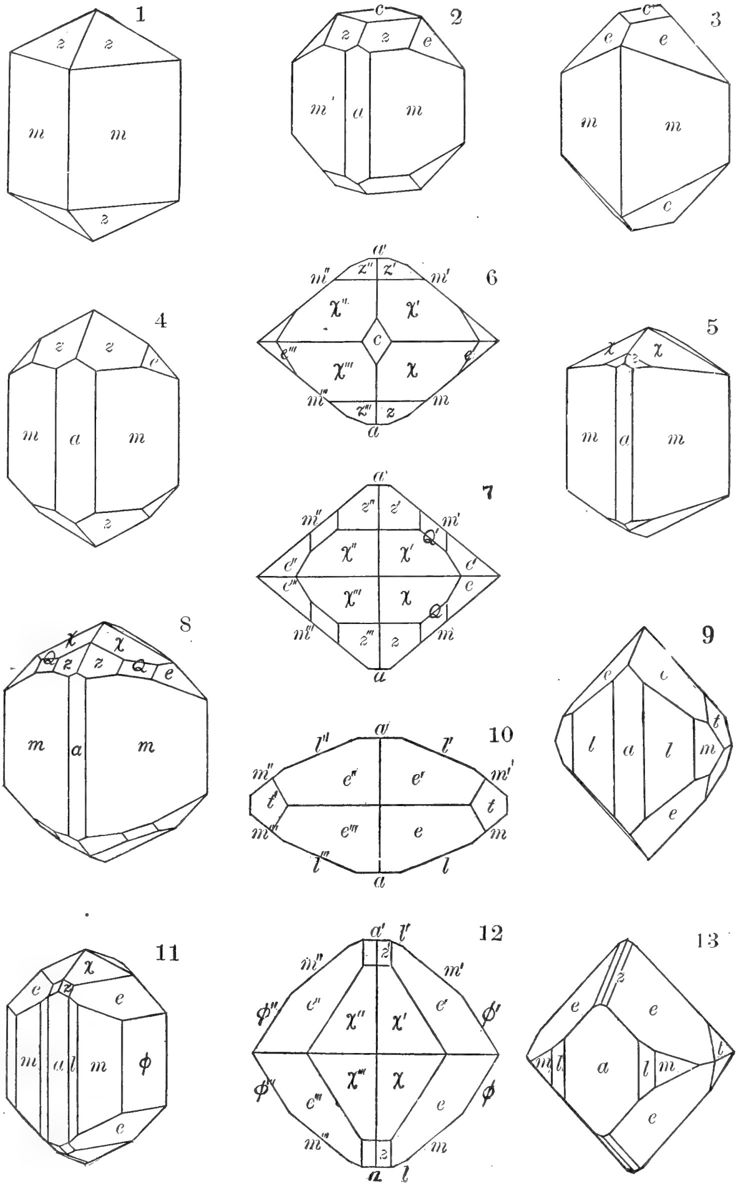
METEORITE

(EXACT SIZE).

FROM GLORIETA MOUNTAIN, SANTA FÉ CO., NEW MEXICO.

PRINTED FROM AN ELECTROTYPE MADE BY DEPOSITING THE COPPER ON THE SURFACE OF THE IRON.

GEORGE F. KUNZ.



BROOKITE FROM MAGNET COVE, ARKANSAS.

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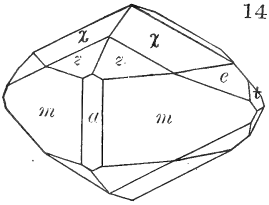

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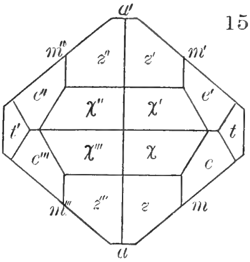

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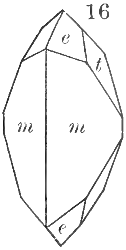

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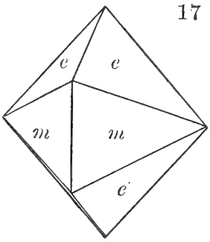

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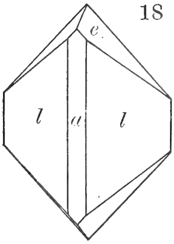

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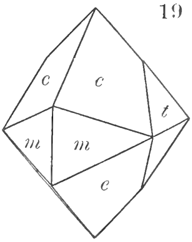

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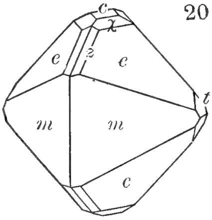

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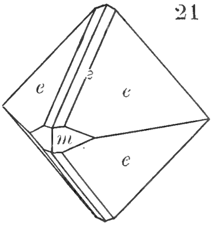

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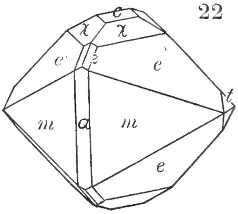

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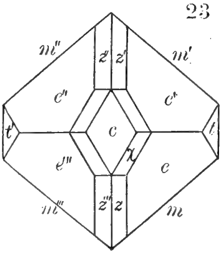

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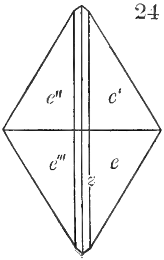

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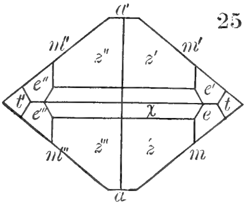
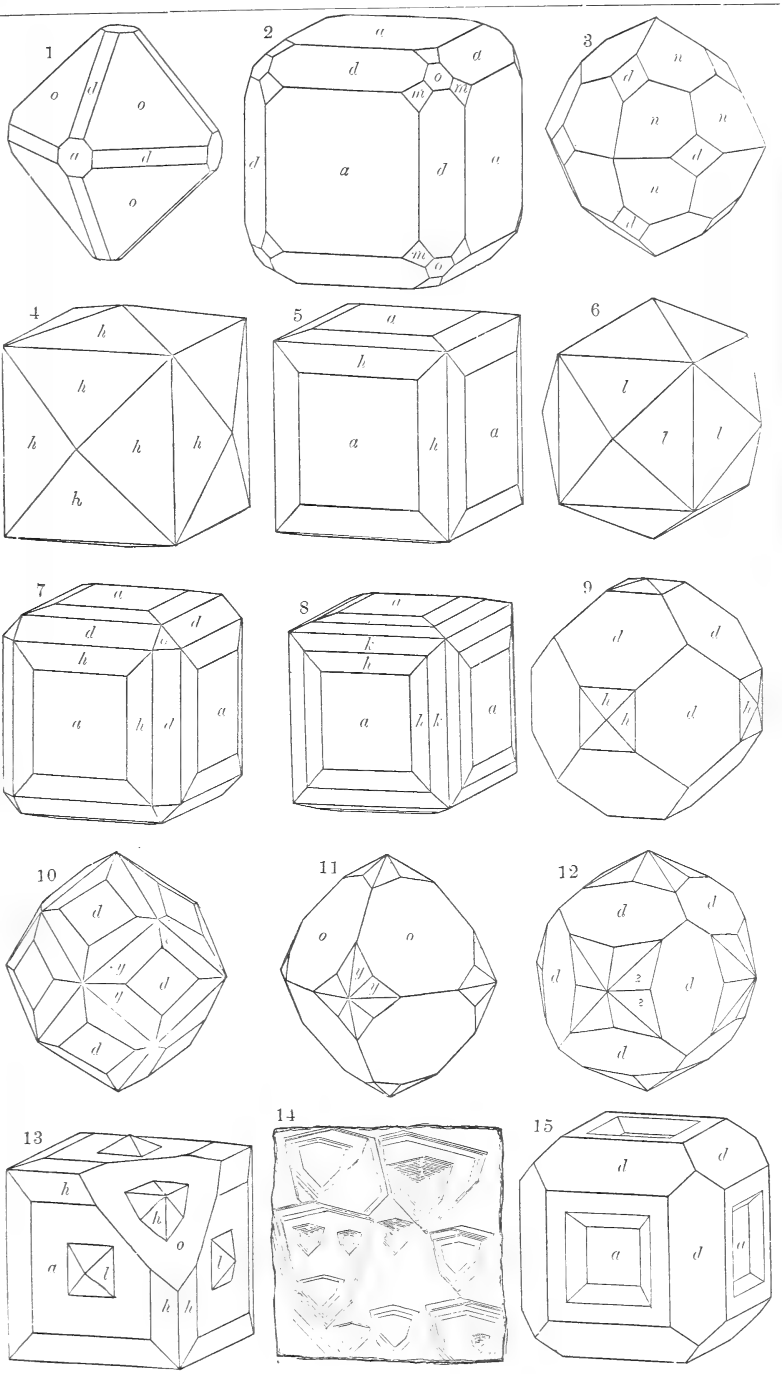


BROOKITE FROM MAGNET COVE, ARKANSAS.



Native Copper—Lake Superior.

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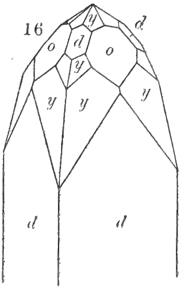

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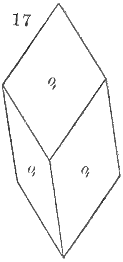

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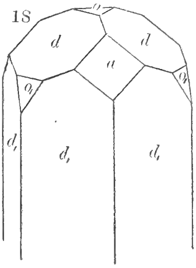

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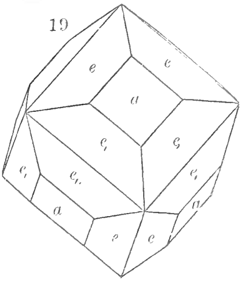

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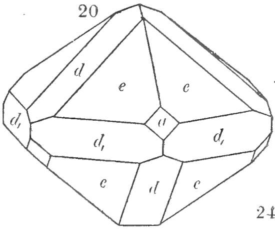

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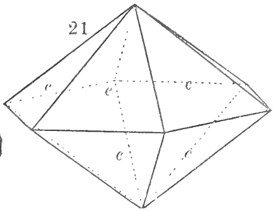

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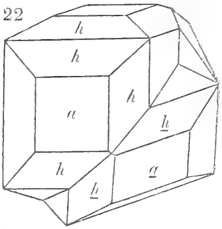

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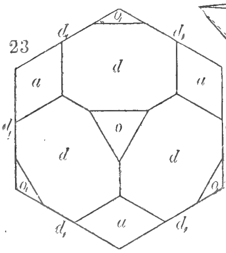

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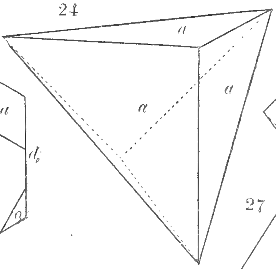

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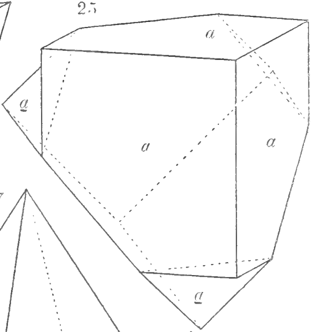

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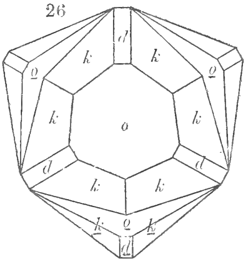

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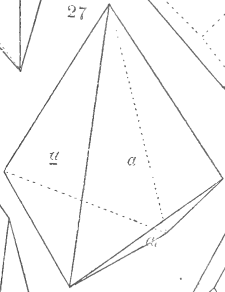

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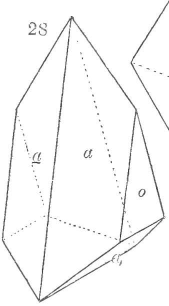

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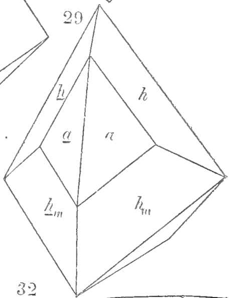

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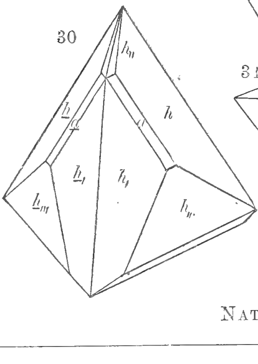

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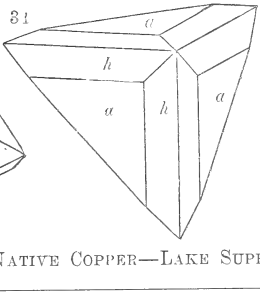

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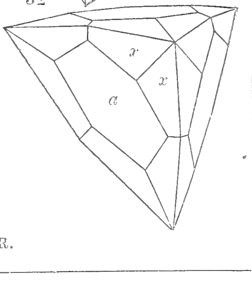
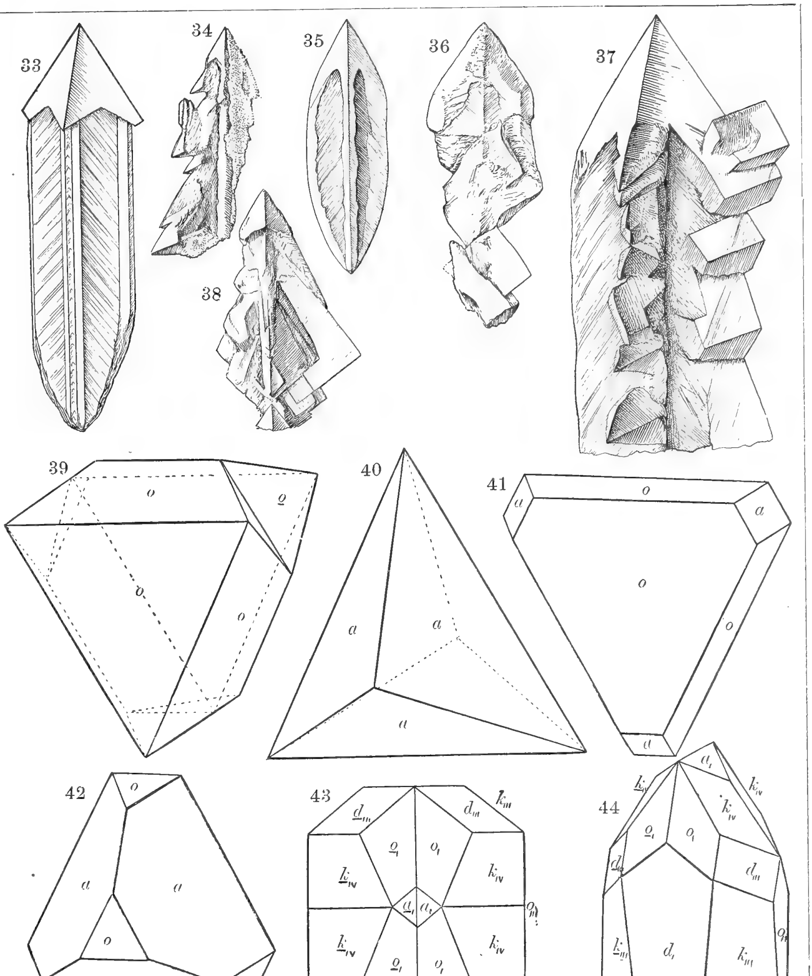
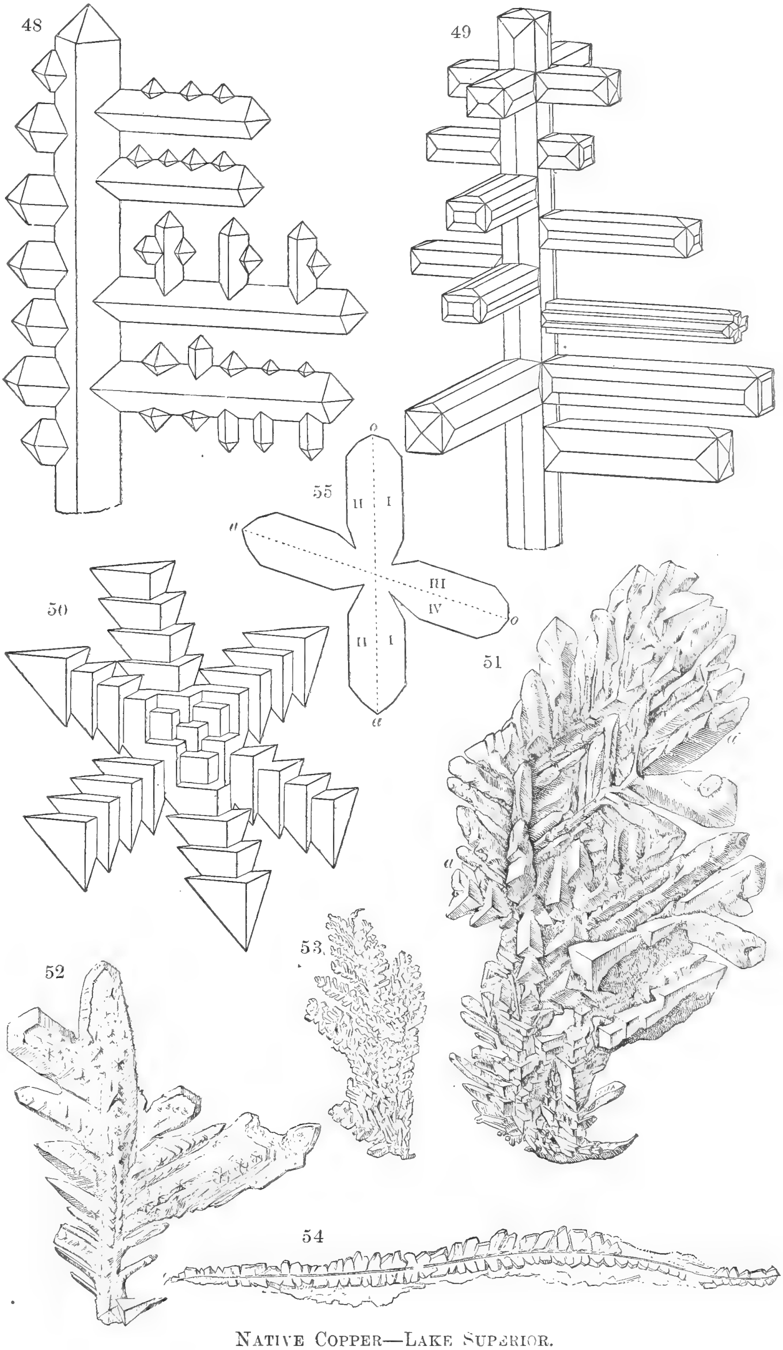


NATIVE COPPER—LAKE SUPERIOR.



Native Copper—Lake Superior.



NATIVE COPPER—LAKE SUPERIOR.

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